The Effects of Fiscal Targets in a Currency Union: a Multi-Country Agent Based-Stock Flow Consistent Model

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Abstract

We present an Agent-Based Stock Flow Consistent Multi-Country model of a Currency Union to analyze the impact of changes in the fiscal regime of member countries, that is permanent changes in the deficit-to-GDP targets that governments commit to comply. Simulations are performed under three scenarios differentiated for the number of member countries. Though we did not try to estimate empirically the parameters of the model, the configuration employed for our artificial Currency Union yields economically reasonable values for the dynamics of key economic variables, broadly comparable with historical data and available stylized facts, in particular referred to the Euro Area which constitutes the natural point of reference for our work. Our policy experiments show that fiscal expansions generally allow to improve the dynamics of real GDP, labor productivity, and employment, though being associated to higher levels of public debt. On the contrary, permanent fiscal contractions have always strong recessive effects and tend to be self-defeating when the Currency Union includes a higher number of countries and international trade between member countries is more prominent, exacerbating real GDP volatility both in the short and long run. The observed increase of average debt-GDP ratios in these scenarios seems to be mainly attributable to the raise of public debt-to-GDP in poorer and less productive countries, which is mirrored by a reduction of the countries' net foreign asset position. In the conclusions we discuss current limitations of the model and we sketch out the future lines of development.

Keywords: Agent Based Macroeconomics, Stock Flow Consistent Models, European Integration, Fiscal Policy.

JEL Codes: E62, F15, C63

1 Introduction

The paper presents an Agent Based-Stock Flow Consistent (AB-SFC) Multi-Country model to analyze the impact of different fiscal regimes on the long term economic dynamics of a monetary union broadly comparable to the European Economic and Monetary Union (EMU).

The computational framework proposed is at once simple in its behavioral assumptions and sophisticated in the structure and types of interactions considered. Simple, in that agents' behavior is based on relatively simple adaptive heuristics. In addition, there is no investment in tangible assets so that labor is the only productive factor and only final goods are produced. Only credit to firms is modeled.Finally, public expenditure takes the form of a lump-sum monetary transfer to households. Still, the model is sophisticated in the following aspects: first, its dynamics endogenously emerges from the decisions undertaken by many heterogeneous agents interacting in a decentralized way on several types of markets (i.e. labor, tradable and nontradable consumption goods, credit, deposit, and bond markets). Furthermore, the model encompasses international flows of both real and financial assets, which arise from trade and credit flows between member countries. Consumers' preferences and firms' products are differentiated using Salop's (1979) circular specification of Hotelling's (1929) locational model. Technological change and sectoral technological spillovers, affecting the evolution of labor productivity across firms and countries, are modeled as an endogenous process related to firms' investment in R&D.

In addition to this, the model also shows several important innovations with respect to the AB macro-modeling literature to which we aim at contributing: to our knowledge, this is one of the first, if not the very first, fully-fledged multi-country AB macroeconomic model presented in the literature.

*The research leading to these results has received funding from the European Union, Seventh Framework Programme FP7, under grant agreement FinMaP no. 612955

Electronic copy available at: https://ssrn.com/abstract=2904953

Indeed most models developed till now either displayed a closed-economy or, at most, a two-country economy. Our model instead can run with a variable number of countries: for the present work experiments were performed under the 2, 6, and 10-countries cases. Secondly, the accounting consistency of the model is ensured by the adoption of an SFC framework (Godley, 1997; Godley and Lavoie, 2007) along the line traced by Caiani et al. (2016, 2017); Deissenberg et al. (2008).Third, instead of assuming that the number of firms is fixed as in most of the macro AB literature where defaulted firms and banks are automatically replaced by an equal number of new entrants, we endogenized equity investment by households and the entry-exit process of firms and banks. The creation of new firms (and banks) is modeled as the outcome of households' savings portfolio allocation between equity participations in new firms and deposit accounts, based on their relative rates of return and their perceived riskiness. Finally, we propose a simple procedure to initialize the model in an SFC manner without having to set initial values of stocks and flows in an arbitrary way, inspired by the logic employed in the "SIM model" presented in Godley and Lavoie (2007).

For the sake of analyzing the impact on our artificial Union of permanent changes in countries' fiscal policy, we first identified a parameter configuration yielding realistic and relatively stable systemic dynamics. Then, we introduce a fiscal policy regime switch occurring at period 500, modeled as a variation of the common fiscal target for public deficits. To analyze the impact of these policies, we first look at their impact on the average values and volatility of main economic aggregates, both in the short and long-run. Then, we also differentiate between high and low income countries to assess if changes in the policy regime affect richer and poorer countries in a symmetric or asymmetric way.

Results show that fiscal expansions generally tend to boost economic growth, technological change[1] and employment, though also increasing debt-GDP ratios. Instead, permanent reductions of fiscal targets exert significant depressive effects on real GDP, labor productivity dynamics, unemployment, and prices. More important, the efficacy of permanent fiscal contractions in reducing the burden of public debt seems to be limited, at least in the long run, to the two-country scenario. On the contrary, in the more realistic scenarios where the Currency Union includes a higher number of countries and the dimension of the common market for tradables is more prominent, fiscal contractions tend to be self-defeating in the long run, increasing, rather than decreasing, average debt-GDP ratios. In these cases fiscal austerity tends to exacerbate recessions, amplifying economic fluctuations both in the short and in the long run. We also show that fiscal contractions tend to impact more on the public finance of poorer (thus less productive) countries causing a remarkable increase of their public debt which explains much of the long-run rise observed in average debt-to-GDP ratios. Finally, we also point out that less productive countries also see their net foreign asset position deteriorating as public debt rises. Less productive countries indeed experience deeper and more frequent Current Account deficits under the fiscal contraction scenarios, which reduce taxable income thereby increasing public deficits.

1.1 Euro imbalances and fiscal consolidation in the EMU: empirical and theoretical disputes

The Great Recession started in 2007 revealed the vulnerability of the EMU. The global economic turmoil displayed very peculiar traits in Europe, compared to the US case, manifesting itself not only as a real and banking crisis, but also as a sovereign debt crisis. Policy interventions launched by European institutions and member states' governments in reaction to these events have mainly gone in two directions. On the monetary policy side, the Central Banks was called to play a more active role as a lender of last resort, both for private banks in distress and for countries experiencing severe financing problems which threatened the financial stability of the Euro area as a whole.[2]

On the fiscal side, while severe fiscal contractions were the distinctive trait of Macroeconomic Adjustment Programmes undertaken by countries in distress, fiscal austerity measures have been exacerbated in all member countries under the Stability and Growth Pact, and as a consequence of the Fiscal Compact. This latter bound signatories countries to transpose into their legal order the provision of the treaty for a balanced national budget.

[1] With the only exception of the two-country case where the increase in real output and productivity is almost negligible.

[2] Under the first respect, unconventional forms of monetary policy, among which the most prominent was the Quantitative Easing, were adopted. As for the latter, ECB President Draghi's famous claim to do"whatever it takes to save the Euro" in the apex of the sovereign debt crisis culminated in the launch of European Financial Stability Facility (EFSF) and the European Financial Stabilisation Mechanism (EFSM), then replaced in 2012 by the European Stability Mechanism (ESM).

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However, the deflationary spiral which invested many southern countries, the rising imbalances between core and peripheral economies, and the endemic fragility of private credit institutions and countries' public finance have put seriously into question the efficacy of these measures. The resurgence of the economic debate on the sustainability of the European Monetary Union project had profound implications on the political debate and its topicality grew dramatically after the 'Brexit'.

Admittedly, fiscal austerity did not enter the scene just in the aftermath of the Euro Crisis. On the contrary, the idea to limit as much as possible the discretion of member countries in conducting fiscal policy, by setting strict bounds to public deficits, was at the very core of both the Maastricht Treaty and the Treaty on the Functioning of the European Union, where the ECB was prohibited from buying government bonds in the primary market.

Such a persistent position in favor of fiscal consolidation policies found its theoretical roots in the traditional Neoclassical postulate that public spending would exert direct and indirect crowing out effects on private expenditure, in particular on investment. The modern refinement of this idea is the so-called "Expansionary Fiscal Contraction Hypothesis", originally proposed by Giavazzi and Pagano (1990) and Alesina and Perotti (1995) and brought back in vogue after Reinhart and Rogoff (2010) contended the existence of a negative relationship between high levels of public debt and economic growth in advanced countries. These authors argued that discretionary fiscal expansions may undermine the solidity of public finance and of the overall financial system, eventually depressing private spending: for example, if consumers behave in a Ricardian way, they will abstain from consumption when fiscal deficits are perceived as unsustainable, making future tax increases more likely. Vice-versa, well-designed fiscal consolidations, that is deep, persistent, and credible cuts in public expenditures may stimulate private consumption and investment, and even improve export dynamics.

The empirical ground of these claims has been harshly criticized by several authors. Herndon et al. (2014), for example, rose serious doubts on Reinhart and Rogoff's work focusing on the alleged arbitrariness of their data sampling procedure and then pointing out serious flaws in their data elaboration, even in the form of trivial coding mistakes. Others, as Guajardo et al. (2011), pointed out that the cyclically adjusted primary balance measures usually adopted in the Expansionary Austerity literature does not completely remove the effects of economic cycles on the evolution of public finances, so that the positive correlation between fiscal restrictions and economic expansions would be just the consequence of a biased measure of fiscal balances. Furthermore, since the causal link between fiscal balances and economic growth is likely to go in both directions, they point out that cyclically adjusted primary balance cannot be treated as an exogenous explicative variable, as usually done in that literature; when a better suited estimation methodology is adopted, fiscal contractions ends up to be consistently recessionary.

However, much of the debate on the role of fiscal stimuli has been geared around the estimation of the magnitude of fiscal multipliers. Gechert and Rannenberg (2014), in an attempt to review the ever growing literature on "state-contingent" fiscal multipliers, provides a meta-regression analysis of fiscal multipliers from a broad set of empirical reduced-form models. Their meta-analysis finds that fiscal multipliers are significantly higher during recessions than during boom phases, and that spending multipliers significantly exceed tax multipliers so that fiscal consolidation should take place during recoveries, being instead avoided during recessions, and should be based on taxes rather than on public spending cuts. Similar results are achieved by Auerbach and Gorodnichenko (2012); Blanchard and Leigh (2013), while Ferraresi et al. (2014) finds that the response of output to fiscal policy shocks is stronger and more persistent when the economy is in a "tight" credit regime. Finally, De Grauwe and Ji (2013) reaches the conclusion that the self-defeating character of fiscal austerity, in particular during recessions, is enhanced in the case of a monetary Union.

On a different level, Botta (2015) points out the theoretical inconsistency of Expansionary Fiscal Contraction Hypothesis, going through a detailed analysis of the policy measures advocated by its supporters and showing that fiscal consolidation might have expansionary outcomes only under extreme, very specific, and uncertain conditions.

Post-Keynesian scholars have opposed as well the view that fiscal profligacy by southern countries, paired with excessive wage growth, were the major cause of the Euro Crisis, implying that austerity and labor market deregulation were essential to restoring order. On the contrary, they trace the origin of the global crisis in the emergence of a debt-driven growth model, which resulted in a rapid increase in private debt ratios and which eventually inflated the real estate bubble. These authors consider the escalation of the crisis into a sovereign debt crisis and a depression in southern Europe as the result of the European Union's peculiar institutional and policy setup, based on the separation of the fiscal

and monetary spaces and designed to impose fiscal discipline and pro-cyclical austerity (Stockhammer et al., 2016). In particular, they insist on the role played by this framework in amplifying trade and Balance of Payment imbalances between core and peripheral European countries (Hein et al., 2011; Semieniuk et al., 1 14; Perez-Caldentey and Vernengo, 2012; Zezza, 2012b).[3]

1.2 Euro imbalances and fiscal consolidation in the EMU: simulation approaches

Besides the empirical and analytical levels, the impact of different fiscal regimes has been widely explored also by means of computational methods based on computer simulations.

Within the DSGE literature, a vision strongly in favor of fiscal consolidation measures has been proposed by Cogan et al. (2010): building on an empirically estimated version of the Smets and Wouters (2007) New Keynesian model of the US economy, they argue that fiscal multipliers are significantly lower than those estimated with traditional structural macroeconomic modelswhich do not account for forward looking rational expectations by individuals and firms, and are consequently unable to grasp the change in economic actors' behavior in response to policy shocks. Christiano et al. (2011), on the contrary, finds that fiscal multipliers can be much larger than one when the zero lower bound on the nominal interest rate binds and stresses that fiscal multipliers are significantly larger when higher spending is coupled with monetary accommodation. Fiscal stimuli are seen as potentially useful also in Corsetti et al. (2009), who show that crowding-in effects on consumption become possible when increases in government spending are carried out under a plausible debt-stabilizing policy that links current stimulus to a subsequent period of spending restraint. Finally, Coenen et al. (4 1) propose an interesting comparison between results of the former three DSGE models developed in the academia and those obtained using seven structural models employed by major policymaking institutions.The analysis of the impact of seven different fiscal instruments shows that the seven models (six of which DSGE) display large fiscal multipliers, that fiscal policy is most effective when accommodated by the monetary policy, and that a permanent fiscal stimulus has significantly lower initial multipliers, reducing output in the long run.

However, as already anticipated, our work aims at giving a contribution to an alternative macroeconomic literature. The economic debate emerged in the aftermath of the Great Recession has casted serious doubts on the theoretical and empirical foundation of DSGE models, questioning the reliability of their policy prescriptions (Trichet, 2010; Blanchard et al., 2012) and fostering a quest for alternative macroeconomic modeling tools: Agent Based macroeconomic models (Delli Gatti et al., 2010), which conceive the economy as a "complex evolving system" (Esptein, 2006), have proven to be well suited to explain the endogenous nature of economic growth, the generation of business cycles, and the emergence of real and financial fragility possibly culminating in severe recessions. This approach provides an alternative way to micro-found models (Gaffeo et al., 2008) where emergent dynamics are the result of the decentralized interactions between heterogeneous, boundedly-rational, adaptive agents. Agent Based models thus provide a powerful framework to test a wide variety of policy schemes. A critical discussion on the limits of DSGE modeling and a detailed comparison between the DSGE and ABM approaches can be found in Caiani et al. (2016) and Fagiolo and Roventini (2016).

As a consequence of the encouraging results obtained within this nascent literature, in the recent years AB models have blossoming. Several applications have been proposed to analyze the effects of fiscal and monetary policies and to deal with macroeconomic imbalances affecting the EMU. For example, Dosi et al. (2013), using a refined version of Dosi et al. (2010), studies the interactions between income distribution and monetary and fiscal policies. They find that fiscal policies dampen the amplitude of business cycles, reduce the likelihood of experiencing huge crises, and may exert a positive effect even on long-term growth. Vice-versa, policy restrictions negatively affect the economic performance. Furthermore, the impact of fiscal policies is greatly enhanced when the distribution of income is skewed toward profits. Dosi et al. (2015) further extends the model to analyze the effects of alternative combinations of fiscal and monetary policies, reaching the conclusion that the most appropriate policy mix to stabilize the economy requires unconstrained counter-cyclical fiscal policies coupled with a monetary policy targeting also employment. On the contrary, fiscal policies comparable to those proposed in the Fiscal Compact have a strong depressive impact, which is exacerbated when

[3] Although moving from a different theoretical perspective, also Holinski et al. (2012) stresses as well the potential risks associated to persistent trade and financial imbalances between the North and South of Europe, advocating better coordinated policies to prevent the emergence of unsustainably large imbalances in the Euro area.

the monetary policy targets only price stability. Similar conclusions are reached by Teglio et al. (2015), building upon Cincotti et al. (2010); Raberto et al. (2012). Riccetti et al. (2013) proposes an AB model with decentralized matching on all markets, finding that an increase in public employment significantly stabilizes the economy at the expense of a slight increase in deficit-to-GDP ratio, which can be almost eliminated through a modest increase in taxation. Dawid et al. (2016) employs a two-country extension of Deissenberg et al. (2008) as a laboratory to analyze several types of fiscal policies aiming to revert Euro imbalances. They find that policies which share the debt-burden of peripheral countries also with core countries are almost ineffective in promoting a convergence. On the contrary, fiscal transfers in favor of households in peripheral regions do exert a positive effect. However, technology oriented subsidies to firms, aiming to improve labor productivity in peripheral regions, are the most effective tool to improve their competitiveness. By employing the closed-economy version of the same model Harting (2015) shows that distinct fiscal policies, such as demand-oriented and supply(technology)-oriented fiscal policies may exert very different effects on the long-run economic performance of the economic system even though they can have similar effects in reducing business cycle volatility.

Our contribution also points to the so-called Stock Flow Consistent approach (Godley and Lavoie, 2007) which stems from the accounting-based modeling tradition started by Brainard and Tobin (1968) and later refined by Godley and Cripps (1983). This modeling approach aims at providing a comprehensive and fully integrated representation of the economy, including all financial transactions. At its base we find the idea that real and financial flows, and the stocks on which they impact, must always satisfy given accounting identities in a social accounting perspective. These identities ensure that there are not black holes in the representation of (real and nominal) stocks and flows, acting as a "conservation of energy principle for economic theory" (Godley and Cripps, 1983). This framework is particularly well suited to model in a realistic and coherent way the financial system - especially legal and private money created through credit - and its relationships with the real side of the economy. In the recent years SFC models have been extensively employed to analyze fiscal, monetary, and macroprudential policies, in particular in the context of a currency Union.

Adopting an SFC framework, Zezza (2012a) suggests that fiscal austerity in the presence of large public debts tends to redistribute income from taxpayers to the owners of such debt: when public debt has been financed by financial markets in foreign countries, interest payments on bonds will redistribute income to foreigners, thereby exacerbating the contractionary impact of austerity on domestic growth. Eventually, this would make a lower debt-to-GDP ratio an unfeasible target. This result suggests that, since public debt is held abroad when a country has been running a current account deficit, the primary concern of policymakers should be to introduce mechanisms for correcting, or at least financing, trade imbalances within the EMU. Duwicquet et al. (2013) presents an SFC two-country model where the southern country is suffering from an over-evaluated Euro, while the northern country enjoys an under-evaluated Euro, boosting its exports. The authors then test different institutional reforms at the Union level to counter these implicit transfers from the South to the North, finding that both fiscal transfers based on a federal budget, and a system of eurobonds may help to counteract trade imbalances in the EMU. Mazier and Valdecantos (2015) extends the previous work proposing a four-country SFC model to study the effects of different exchange-rate arrangements. Among the proposed arrangements, they focus their attention on the adoption of a double-Euro currency that may help to reduce imbalances between surplus and deficit countries in the Eurozone.

Though accounting-based models have found fertile soil in the Post-Keynesian tradition (see Dos Santos (2006) and Caverzasi and Godin (2015) for a literature review), in recent years they gained more and more interest also outside this community. Caiani et al. (2014a,b) for example, present two applications of the SFC methodology to the study of Great Surges of Development in an evolutionary-Neo Schumpeterian perspective, stressing the interdependency between innovation and finance. In 2011, the Bank of England used a similar approach to analyze the mechanics of financial instability. Barwell and Burrows (2011) advocates the diffusion of macroeconomic approaches that stress the importance of balance sheet linkages. On a similar ground (though in a general equilibrium framework), Duca and Muellbauer (2013) revisits Tobin's efforts to understand financial-real linkages, and proposes a modeling framework for analyzing households' flows-off-fund and consumption in an integrated way. Finally, the Bank of England has recently presented a Stock Flow Consistent Model to perform scenario analysis on the UK economy (Burgess et al., 2016): their fiscal expansion experiment considers an increase of 10% in government spending, phased over three years, finding a fiscal multiplier around one.

AB and SFC models may greatly benefit from a mutual integration (Deissenberg et al., 2008;

Caiani et al., 2014a, 2016, 2017). In particular, the adoption of an AB-SFC framework provides a powerful tool to check the internal theoretical consistency of an AB model and an effective expedient to discipline AB practitioners (Caiani and Caverzasi, 2017). A fusion of the two approaches could help AB macroeconomic modeling to set itself as an alternative paradigm to DSGE models (Farmer and Foley, 2009) responding to the call recently made by FED chair Jellen (Jellen, 2016) for models capable of addressing the role of agents' heterogeneity and real-financial linkages.

The rest of the paper is structured as follows: the next section goes through the detailed behavioral assumptions made and present the logic employed to define the initial setup of our simulation experiments. Section 3.2 first checks the consistency of our results with available empirical stylized facts, nd then displays and discusses the results of our policy experiments. Finally, section 4 consider the limits of the present work and briefly sketch out future applications and refinements.

2 The Model

The artificial economy depicted in the model is a currency Union composed of K countries. Each country is populated by the same number H of households and by an endogenously varying number of firms (I_t) and banks (Z_t). Firms produce their output out of labor only and are divided into two groups according to whether they produce tradable or nontradable final goods: the former can be purchased by households in all member countries whereas the latter can be sold only on the national market for consumption goods. The process of entry and exit of firms and banks is shaped so to keep both the relative dimension of the manufacturing and banking sectors and the proportion between tradable and nontradable firms roughly stable.

International trade between countries gives rise to international movements of financial resources in the form of deposits and bank reserves transfers. International flows of financial assets may also originate from the fact that firms can try to satisfy their funding needs by asking loans to both domestic and foreign banks. Similarly, banks can purchase bonds issued by any member country. On the contrary, for simplicity reasons, we assume that there is no international labor mobility and that households can invest only in domestic firms.

The government of each country collects taxes on households' income and on profits of firms and banks. Public spending takes the form of a lump-sum money transfer in favor of households. Countries are subject to the same regulatory framework, having common deficit-to-GDP targets that they try to attain by adaptively modifying taxation rates and the level of public spending.

The System of Central Banks of the currency Union operates under the control of the Union Central Bank and includes K national Central Banks, one for each country. The Union Central Bank employs a Taylor rule to set the common discount interest rate applied on cash advances. National Central Banks accommodate commercial banks' demand for cash advances through the marginal lending facility. Furthermore, they possibly buy the residual amount of their country's public debt bonds which have not been purchased by private banks. In this way they also inject reserves into the economic system (Caiani et al., 2016).

The model endogenizes technological change, which arises from firms' innovative investments and incrementally increases labor productivity. Productivity enhancing innovations can be achieved in two ways: through direct incremental innovations, or by exploiting sectoral spillovers through imitation which allows less productive firms to catch up with the sectoral productive standards (Dosi et al., 2010). Together with aggregate demand, technological change is the fundamental engine of long-term real growth in the model and plays a crucial role in determining firms' and countries' international competitiveness, thereby impacting on international trade patterns and countries' differentiation.

Finally, we follow Riccetti et al. (2014) and Caiani et al. (2016) in assuming that agents interact on the different markets in a decentralized way, following specific matching protocols. The structure of our artificial economy encompasses six types of market: national 'nontradable' good markets, national labor markets and national deposit markets, a common 'tradable' good market, and common credit and bond markets.

The following two subsections describe in details agents' behaviors and interactions.

2.1 Agents

2.1.1 Households

Households are at the same time workers, shareholders, and consumers.

As a worker, each household supplies a given quantity of labor ($l^S = 1$) in each period of the simulation to ψ randomly chosen potential employers (see section 2.1.2). It might be the case that a firm does not want to hire a worker at full time because her residual demand for labor is lower than the worker's supply. In other cases a firm may want to employ at full time a worker, but being prevented from doing it by liquidity shortages. In these situations workers can return on the labor market to offer their residual labor force to the other $\psi - 1$ potential employers. As a consequence, workers can be employed in different firms (l_{hit}, where i indicates one of the n employers of the household h), receiving different wages from each employer (w_{hit}). Yet, total labor actually sold to firms ($l_{ht} = \sum_i^n l_{hit}$) may still be lower than the quantity supplied (l^S) if the worker remains unemployed or if she/he is employed part-time.

Workers do not accept vacant positions if the offered wage is below their reservation wage (w_{ht}). This latter varies according to an adaptive rule based on the worker's past employment situation. Workers decrease their reservation wage by a stochastic amount whenever they have not been fully employed in the last period. Instead, when $l^S = l_{h,t-1}$ they have a positive probability $Pr(u_t)$ of increasing their reservation wage which is inversely related to the level of unemployment, as shown in eq.1. This latter condition implies that workers' wage claims are negatively affected by higher levels of unemployment, with the parameter $\upsilon > 0$ shaping the strength of this relationship: the higher $\upsilon > 0$, the lower the probability of increasing demanded wages for given levels of unemployment.

$$w_{ht} = \begin{cases} w_{h,t-1}(1 + U[0,\delta]), & \text{if } l^S - l_{h,t-1} = 0 \text{ with } Pr(u_t) = e^{-\upsilon u_{t-1}} \\ w_{h,t-1}(1 - U[0,\delta]), & \text{if } l^S - l_{h,t-1} < 0 \end{cases} \tag{1}$$

Furthermore, we assume that firms employ workers for production and R&D activities indifferently and that financial resources devoted to innovative investments (IN_{it}, see section 2.1.2) are distributed across their employees (l_{it}) proportionally to the quantity of labor individually supplied (l_{hit}). Investment in R&D thus generates additional wages for workers.

In addition to labor income households also receive interests on their deposits D_{ht} from banks (computed at the interest rate r_{dt}), dividends from participated firms and banks (Div_{ht}), and a tax-exempt government transfer (TF_t).

All in all, households' gross and net income (i.e. after taxation), indicated respectively by y_{ht} and y^D_{ht}, are expressed by:

$$y_{ht} = \sum_i^n w_{hit} l_{hit} + r_{dt} D_{ht} + Div_{ht} + \sum_i^n IN_{ht} \frac{l_{hit}}{l_{it}} \tag{2}$$

$$y^D_{ht} = (1 - \tau_t) y_{ht} + TF_t \tag{3}$$

where τ_t is the tax rate in the current period.

Desired consumption (C^D_{it}) is a linear function of current disposable income and wealth held in the form of deposits, with fixed marginal propensities c_y and c_d:

$$C^D_{ht} = c_y y^D_{ht} + c_d D_{ht} \tag{4}$$

where $0 < c_y < 1$ and $0 < c_d < 1$. This specification of the consumption function also ensures that the level of desired consumption chosen by households is always financially feasible, given their available deposits.

Consumers distribute their total demand for consumption goods between tradable (C^{DT}_{ht}) and nontradable (C^{DNT}_{ht}) goods with fixed proportions c_T and $1 - c_T$ respectively, where c_T is the same parameter affecting the numerosity of tradable and nontradable firms through the entry procedure (see section 2.1.6).

$$C^{DT}_{ht} = c_T C^D_{ht} \tag{5}$$

$$C^{DNT}_{ht} = (1 - c_T) C^D_{ht} \tag{6}$$

The model employs a circular Hotelling's locational specification (Salop, 1979) of preferences and varieties, assuming that good varieties produced by firms and consumers' variety preferences are randomly located on a circle (Figure 1) with unitary diameter. According to this approach, a random radian value is associated to each firm (ω_i) and to each consumer (ω_h). When they choose their preferred consumption goods suppliers, consumers thus take into account not only the price, but also the variety of the feasible alternatives: the lower the firm's price p_{it} compared to the average level (P_{it}), and the smaller the distance (d_{hi}) between the firm's and the consumer's location on the circle, the higher the utility (u_{hit}) that the consumer is able to extract from goods supplied by the firm.

$$u_{hit} = \frac{1}{d_{hi}^{\beta}} \frac{P_t}{p_{it}} \tag{7}$$

where $\beta \geq 0$ is the parameter weighting households' preference for variety. The lower β, the more consumer perceive consumption goods as homogeneous, thereby giving more weight to price differences when sorting consumption alternatives. The distance between the firm's and the consumer's location coincides with the length of the arch between them. Since the diameter of the circle is set equal to one, this can be computed as:

$$d_{ht} = sin(min[|\omega_h - \omega_i|, 2\pi - (|\omega_h - \omega_i|)]/2) \tag{8}$$

Households access tradable and nontradable markets in a random order, they sample ψ potential suppliers, and they express their preferences following the procedure explained above. Consumers buy the maximum possible amount of their preferred good given their demand for consumption goods and the quantities supplied by the selected seller. In the case of supply constraints, consumers can turn to the second, third, fourth etc. best supplier to satisfy their demand, till they eventually satisfy their demand or exhaust the list of the ψ potential partners.

Households hold their wealth (NW_{ht}) partly in the form of deposit accounts at commercial banks D_{ht}, which yield a positive interest rate, and partly as participations in the equity of firms and banks A_{ht}, yielding dividends when profits of participated firms are positive. Therefore, in every period they have to decide how to allocate their savings between these two types of assets.

This decision is based on an endogenously determined liquidity preference lp_{ht} which depends on the past rates of return yielded by the two types of assets. Since deposits are considered as a risk-free asset, whereas equity investment are risky, the rate of return on equity investment is weighted by its perceived riskiness, measured by the past extinction rate of firms and banks (i.e. a proxy for firms and banks' probability of default): $Pr_t^{default} = \frac{I_{t-1}^{default} + Z_{t-1}^{default}}{I_{t-1} + Z_{t-1}}$

The liquidity preference of each households in then determined as:

$$lp_{h,t} = \begin{cases} \lambda e^{-(\frac{Div_{h,t-1}}{A_{h,t-1}}(1-Pr_t^{default})-r_{dt})} & \text{if } \frac{Div_{h,t-1}}{A_{h,t-1}} \geq r_{dt} \text{ and } A_{h,t-1} \geq 0 \\ \lambda & \text{if } \frac{Div_{h,t-1}}{A_{h,t-1}} < r_{dt} \text{ or } A_{h,t-1} = 0 \end{cases} \tag{9}$$

with $0 < \lambda < 1$.

If we indicate by $NW_{ht}^D = NW_{ht-1} + y_{ht}^D - C_{ht}^D$ households' expected level of net-worth based on their planned consumption, we can derive the desired level of equity and deposits as:

$$A_{ht}^D = max\left\{A_{ht-1}, (1 - lp_{h,t})NW_{ht}^D\right\} \tag{10}$$

$$D_{ht}^D = NW_{ht}^D - (A_{ht}^D - A_{ht-1}) \tag{11}$$

where $A_{ht}^D - A_{ht-1}$ is the desired investment in equity, which is bound to be non-negative.[4]

Still, notice that since consumption may be frustrated by supply constraints, actual consumption (C_{it}) may be lower than desired (C_{it}^D), so that NW_{ht} may be greater than planned (NW_{ht}^D), being savings higher: $S_{ht} = y_{ht}^D - C_{ht}$. In this case we assume that deposits act as buffer stock while investment in equity sticks to its planned level A_{ht}^D, that is: $D_{ht} = NW_{ht} - (A_{ht}^D - A_{ht-1}) > NW_{ht}^D$.

Households having a positive desired investment will then act as entrepreneurs and try to create a new firm (or a new bank). This requires several investors to come together in order to raise the amount of funds required for the foundation of the new enterprise. This threshold level is determined

[4]Indeed, for simplicity reasons, we abstract from the possibility that households want to disinvest from firms by liquidating their participations.

according to the entry procedure explained in section 2.1.6. If the level of investment by households is not sufficient to exceed the threshold, no firm (bank) is created and households will abstain from investing in the current period, with deposits acting again as buffer stock, ending up to be higher than originally planned. Conversely, if desired investment by households is high, it is possible that more than one firm (bank) enters the market.

Finally, in each period households choose their deposit bank randomly since every bank offers the same interest rate r_{dt} for simplicity reasons.

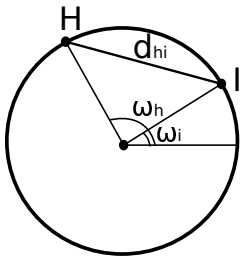

Figure 1: Hotelling circle example. H expresses household variety preferences associated to ω_h. I is the variety produced by firm i associated to ω_i. The distance between household and firm varieties (d_{hi}) is equal to the arch $\overline{HI}$.

2.1.2 Firms

Firms produce final goods and are classified into tradable and nontradable according to the type of good produced: tradable firms offer their goods in an internationally integrated market, while nontradable producers sell their output on the domestic market. Labor is the only production factor and it is employed both for production and innovation purposes.

Firms' production plans depend on their sales expectations and the level of inventories inherited from the past. Furthermore, we assume that firms want to hold a certain amount of real inventories, expressed as a share θ of expected sales, as a buffer against unexpected demand swings (Steindl, 1952) and to avoid frustrating customers with supply constraints (Lavoie, 1992). We indicate by $q_{i,t}$ the (real) output produced by firm i in period t, by $\hat{q}_{i,t}$ the quantities sold, by p_{it} their selling price, by $q^e_{i,t}$ firm's (real) sales expectations, and by $q^{tot}_{i,t} = q_{i,t} + inv_{i,t}$ the total amount of goods available for sales, equal to current production plus inventories.

Prices and expectations are revised adaptively from period to period according to the following scheme:

$$\textit{if } \hat{q}_{i,t-1} \geq \hat{q}^e_{i,t-1} : \begin{cases} \hat{q}^e_{i,t} = \hat{q}^e_{i,t}(1 + U[0,\delta]) \\ p_{it} = p_{i,t-1}(1 + U[0,\delta]) \end{cases} \tag{12}$$

$$\textit{if } \hat{q}_{i,t-1} < \hat{q}^e_{i,t-1} \textit{ and } q^{tot}_{i,t-1} > \hat{q}_{i,t-1} : \begin{cases} \hat{q}^e_{i,t} = \hat{q}^e_{i,t}(1 - U[0,\delta]) \\ p_{it} = p_{i,t-1}(1 - U[0,\delta]) \end{cases} \tag{13}$$

$$\textit{if } \hat{q}_{i,t-1} < \hat{q}^e_{i,t-1} \textit{ and } q^{tot}_{i,t-1} = \hat{q}_{i,t-1} : \begin{cases} \hat{q}^e_{i,t} = \hat{q}^e_{i,t-1} \\ p_{it} = p_{it-1} \end{cases} \tag{14}$$

Equation 12 states that when past sales exceeded expectations, firms adaptively increase both sales expectations and their selling price. By increasing prices they aim to increase their profit margin. When instead past sales were below their expected value and no supply constraint was binding (equation 13), both expectations and prices are revised downwardly. By reducing prices they try to make their output more attractive to customers, thereby improving their sales performance. Finally, when firms' past sales were below expectations despite firms had exhausted all their available supply (equation 14) neither the price nor sales expectations are revised. Indeed, in this case firms cannot be sure that they would have not been able to attain the expected level of sales if supply constraints were not binding, nor they can be sure of the contrary. This justifies a 'conservative' behavior.

Prices have a lower bound represented by unit costs of production, that is: $p_{it} \geq \frac{w_{it}}{\phi_{it}}$, where ϕ_{it} is the firm's current level of labor productivity. The desired level of output for the current period is then

determined as:

$$q_{it}^D = q_{i,t}^e(1+\theta) - inv_{it} \tag{15}$$

The demand for labor can be derived as: $l_{it}^D = q_{it}^D/\phi_{it}$ However, this level of demand is feasible only if the firm has enough funds to pay wages ($w_{it}l_{it}^D$), otherwise labor demand is reduced accordingly. Labor demand by firms may be frustrated by supply constraints, for example because the economy is already at full employment or because the salary offered is too low. Indeed, on the labor market firms demanding a positive quantity of labor l_{it}^D at a wage w_{it} interact with workers who supply a quantity l^S of labor force, having a reservation wage equal to w_{ht}. Households enter the labor market in a random order, randomly select ψ potential employers and choose the first one who offers a wage above their reservation level. If none of the ψ potential employers meets this condition, the household remains unemployed. Since actual production depends on the quantity of labor effectively employed, which may differ from demanded quantities for the reasons explained above, also actual output may be lower than desired one.

The salary offered by firms changes according to the difference between labor demanded ($l_{i,t-1}^D$) and labor actually employed in the previous period ($l_{i,t-1}$). When labor employed was below labor demanded, firms increase their offered salary to attract workers. When there was no discrepancy, firms have a positive probability of reducing wages, thus trying to increase profit margins. This probability is shaped following the same economic intuition behind workers' wage revision rule presented in section 2.1.1, being defined as: $Pr(u_t) = 1 - e^{-u_t \upsilon}$, where the parameter υ is the same adopted in equation 1.

$$w_{it} = \begin{cases} w_{i,t-1}(1+U[0,\delta]), & \text{if } l_{i,t-1}^D - l_{i,t-1} = 0 \\ w_{i,t-1}(1-U[0,\delta]), & \text{if } l_{i,t-1}^D - l_{i,t-1} > 0 \text{ with } Pr(u_t) \end{cases} \tag{16}$$

Firms can also increase their profit margin by improving their productivity ϕ_{it}, thereby reducing unit labor costs. Labor productivity in turn can be increased either through incremental innovations, or by exploiting spillovers at the sectoral level through imitation which allows less productive firms to catch up with leading firms. Both results can be achieved through firms' investment in R&D activity. We assume that every firm, in every period, invest in productivity enhancing activities a given share of its expected wage bill:[5]

$$IN_{it}^D = \gamma w_{it} l_{it}^D \tag{17}$$

IN_{it}^D will be equal to actual R&D investment IN_{it} only if the firm does not face any financial. Indeed, as for production, also firms' innovative investment can be constrained if they lack the necessary liquid funds, so that the actual spending on productivity enhancing activities may be lower than desired. The amount of resources invested in R&D determines the probabilities of enhancing firm's productivity through either an incremental innovation or sectoral spillovers (Dosi et al., 2010). For simplicity reasons we assume these two probabilities to be equal. For firms producing a tradable good this is defined as:

$$Pr_{IN_t}^T = 1 - e^{\frac{-\nu IN_{it}}{\Phi_t^T P_t^T}} \tag{18}$$

$$\tag{19}$$

where P_t^T is the average international price of tradables and Phi_t^T is the average labor productivity of tradable firms in the Union. Both are calculated as a weighted average, with weights represented by firms' market shares. Similarly, for nontradable firms:

$$Pr_{IN_t}^{NT} = 1 - e^{\frac{-\nu IN_{it}}{\Phi_t^{NT} P_t^{NT}}} \tag{20}$$

$$\tag{21}$$

where P_t^{NT} is the average domestic price of nontradable goods and Phi_t^{NT} is the national average labor productivity of nontradable firms, both being weighted for firms' market shares.

Equations 18 and 20 show that the two probabilities of success are a non-linear increasing function of the real investment on productivity-enhancing activities (IN_{it}/P_t^T and IN_{it}/P_t^{NT} for tradable and nontradable firms), normalized by the sector average level of productivity (Φ_t^T and Φ_t^{NT} respectively).[6]

[5] Resources dedicated to R&D are distributed across employees, as explained before, summing up to their wages.

[6] This normalization is required in order to prevent Pr_{IN_t} from increasing with the higher levels of productivity Φ_t achieved as the simulation goes on: indeed, higher levels of labor productivity allow to produce increasing quantities

Given the probabilities of success, firms make a first draw to determine whether they achieve an innovation. When successful, their labor productivity is increased stochastically, as described in equation 22:

$$\phi_{i,t+1} = \phi_{i,t}(1 + U[0, \delta]) \tag{22}$$

Firms having productive standards below the sector average (i.e. a level of productivity below the average) can also try to exploit sectoral spillovers through imitation: in an attempt to catch up with leading firms (i.e. those with productivity higher than the sector average) they then make a second draw with the same probability of success. If successful, they are enabled to partially close the gap with the standards of production in the sector and to extract a new level of productivity defined as follows. For tradable firms:

$$\phi_{i,t+1} = \phi_{i,t} + U[0, (Phi_t^T - phi_{i,t})] \ \textit{if} \ \phi_{i,t} < \Phi_t^T \tag{23}$$

For nontradable producers:

$$\phi_{i,t+1} = \phi_{i,t} + U[0, (Phi_t^{NT} - phi_{i,t})] \ \textit{if} \ \phi_{i,t} < \Phi_t^{NT} \tag{24}$$

The new level of productivity is embed in the production process starting from the subsequent period.

Firms' production (i.e. labor demand) and R&D investment can be financed using both internal funds accumulated through time (D_{it}) and external funding in the form of loans asked to domestic and foreign banks (L_{it}). Following a well-established tradition in AB modeling, inspired by the 'Pecking Order Theory of Finance' (Meyers, 1984), we assume that firms resort to external financing when internal funding possibilities have been completely exhausted, since the cost of external finance is usually higher due to market imperfections and information asymmetries.

Accordingly, the demand for loans by firms can be expressed as:

$$L_{it}^D = \begin{cases} w_{it} l_{it}^D + IN_{it}^D - D_{it}, & \text{if } w_{it} l_{it}^D + IN_{it}^D > D_{it} \\ 0, & \text{if } w_{it} l_{it}^D + IN_{it}^D \leq D_{it} \end{cases} \tag{25}$$

Firms may be financially-constrained as the amount of credit actually received (L_{it}) may be lower than demanded (see section 2.1.3): $L_{it} \leq L_{it}^D$. This happens when banks have already exhausted the total amount of loans they were willing to supply in a given period or if none of them is willing to provide credit to the firm, due to individual credit rationing (see section 2.1.3). However, firms may try to fulfill their financing needs asking credit to all banks. For simplicity reasons, in this first version of the model loans are assumed to be granted and repaid within the same period.[7] When financially constrained, firms give priority to production rather than to R&D.

As for households, also firms randomly choose their deposit bank, receiving an interest r_{dt} on the amounts deposited. Profits are then computed as the sum of revenues from sales ($p_{it} q_{it}$), interests received on deposits held at banks ($r_{dt} D_{it}$), and the nominal variation of inventories $\Delta INV_{i,t}$[8], minus labor expenditure for production ($w_{it} l_{it}$) and R&D activities(IN_{it}), and credit costs ($r_{it} L_{it}$)):

$$\pi_{it} = p_{it} q_{it} + r_{dt} D_{it} + \Delta INV_{i,t} - w_{it} l_{it} - IN_{it} - r_{it} L_{it} \tag{26}$$

If we omit the variation of inventories from equation 26, we obtain a measure of the the net operating cash flows generated by the firm, which we indicate by π_{it}^*. When $\pi_{it}^* > 0$) firms pay taxes

of goods with the same amount of labor. A stable or increasing pattern of real output, and a non-exploding pattern of unemployment can then be achieved only if the purchasing power of households grows faster than prices, thereby absorbing this increased productive capacity. Since most of this purchasing power is represented by wages paid by firms, and given that innovative efforts are proportional to the expected wage bill of firms, IN_{it}/P_t^{NT} will generally increase as Φ_t grows. Therefore, this asks to correct real investment in innovation for Φ_t^{NT} as well, in order avoid an unjustified ever-lasting rise of Pr_{IN_t}.

[7] Though very common in the AB literature, this represents a very strong simplification, as throughly explained in Caiani et al. (2016). In this first application of our multi-country model, this decision was mainly motivated by the need to dampen its complexity in order to avoid over-complicating its dynamics. In the present work, the financial side thus remains relatively sketchy whereas we gave more attention to the real side of the economy and how the process of international competition between firms and countries impacts on the economic performance of member countries, and the Union as a whole.

[8] These latter are evaluated at their unit cost of production, in accordance with accounting standards: $\Delta INV_{i,t} = (inv_{i,t} - inv_{i,t-1}) \frac{w_{it}}{\phi_{it}})$

(T^{π}_{it}) and distribute to equity holders a share ρ of their residual net cash inflow as dividends (Div^{π}_{it}). Since profits are generated at the end of period t - when public spending, tax payments on income of households, and consumption have already taken place - taxes on profits generated in period t are paid in period $t+1$. Accordingly, also dividends generated in period t are paid to equity holders in period $t+1$.

$$T^{\pi}_{it} = \begin{cases} \tau_t \pi^*_{it}, & \text{if } \pi^*_{it} > 0 \\ 0, & \text{if } \pi^*_{it} \leq 0 \end{cases} \tag{27}$$

$$Div^{\pi}_{it} = \begin{cases} \rho(\pi^*_{it} - T^{\pi}_{it}), & \text{if } \pi^*_{it} > 0 \\ 0, & \text{if } \pi^*_{it} \leq 0 \end{cases} \tag{28}$$

Dividends are distributed to equity holders proportionally to their participation (i.e. the capital invested in the firm).

Retained net profits increase firms' net worth:

$$A_{i,t+1} = A_{it} + \pi^*_{it} - T^{\pi}_{it} - Div^{\pi}_{it} \tag{29}$$

Since firms belong to households who originally invested in their creation, as $A_{i,t+1}$ increases, also equity holders' participations are increased accordingly.

2.1.3 Banks

Banks offer demand deposit accounts to households and firms, paying an interest r_{dt} equal to a constant fraction ζ of the discount rate r_t fixed by the Central Bank of the Currency Union. In addition, banks endogenously create means of payment by providing credit to firms. Indeed, as it happens in reality, every new loan granted by a bank, which is an asset for her, is immediately balanced by the creation of a matching liability in the form of a deposit for the borrower, both being created ex-nihilo. This implies that banks' credit supply is not constrained by the amount of deposits already in circulation. On the contrary, their credit supply is theoretically infinite, being only limited by their own assessment of the risk and the profitability associated to each loan project. However, we assume that in order to avoid taking excessive risks, the maximum amount of credit that banks are willing to supply in any given period is a multiple μ_1 of their equity A_{zt}: $L^{DS}_{zt} = \mu_1 A_{zt}$

Banks receive credit applications both from national and foreign firms. For each loan application received by a bank, there is a given probability that the loan will be granted ($Pr(L_{it})$). In addition to this credit rationing mechanism, banks also discriminate borrowers by applying different interest rates (r_{it}). Both the probability of receiving credit ($Pr(L_{it})$) and the interest rate on loans are a function of the borrowers' target leverage, computed as the ratio between their demand for loans (L^D_{it}) and their net-worth (A_{it}):

$$Pr(L_{it}) = e^{-\iota_l \frac{L^D_{it}}{A_{it}}} \tag{30}$$

$$r_{it} = \chi \frac{L^D_{it}}{A_{it}} + r_t \tag{31}$$

Banks are subject to minimal reserve requirements, expressed as a share μ_2 of their deposits:

$$R^M_{zt} = \mu_2 D_{zt} \tag{32}$$

Reserves are held at the national Central Bank and yield a fixed interest rate r_{re}. Whenever reserves R^M_{zt} are below this minimum level, banks apply to the Central Bank lending facility, asking cash advances (L_{zCBt}) to restore the mandated liquidity ratio. National Central Banks accommodate these requests, receiving the discount rate r_t on funds lent. If instead banks have reserves in excess with respect to the mandatory level, these can be invested in the purchase of bonds (B^D_{zt}) issued by any member country k, which bring an interest rate r_{bkt} (see equation 48). In each period of the simulation, bonds tranches issued by governments of the Union are piled up in a random order. Then, commercial

banks access the bond market in a random order and examine each tranche, having a probability of purchasing which depends on the riskiness associated to the country, and defined as:

$$Pr(b_{kt}) = e^{-\iota_b \frac{B_{kt}}{Y_{kt}}} \tag{33}$$

$$\tag{34}$$

Each bank goes through the pile of bond tranches till it eventually exhausts her demand, or there are no bonds to be sold left.

Therefore banks' profits (π_{zt}) are equal to:

$$\pi_{zt} = \sum_{i}^{n} r_{it} L_{izt} + r_{bt} B_{zt} + r_{re} R_{zt} - BD_{izt} - r_{dt} D_{zt} - r_t L_{zCBt} \tag{35}$$

where (BD_{izt}) indicates "bad debt", that is loans not (entirely) repaid as a consequence of a borrower's default.

When profits are positive ($\pi_{zt} > 0$), banks pay taxes (T^{π}_{it}) and distribute to equity holders a share ρ of net profits (Div^{π}_{zt}). As for firms, dividends are distributed among investors proportionally to the share of the bank's equity they own.

$$T^{\pi}_{zt} = \begin{cases} \tau_t \pi_{zt}, & \text{if } \pi_{zt} > 0 \\ 0, & \text{if } \pi_{zt} \leq 0 \end{cases} \tag{36}$$

$$Div^{\pi}_{zt} = \begin{cases} \rho(\pi_{zt} - T^{\pi}_{zt}), & \text{if } \pi_{zt} > 0 \\ 0, & \text{if } \pi_{zt} \leq 0 \end{cases} \tag{37}$$

Retained profits after taxes then increase banks' net-worth:

$$A_{z,t+1} = A_{zt} + \pi_{zt} - T^{\pi}_{zt} - Div^{\pi}_{zt} \tag{38}$$

As $A_{z,t+1}$ varies, also households' participation in the bank, and thus households' net-worth, is revised accordingly.

2.1.4 Central Banks

The Central Bank of the Currency Union operates through the Union System of Central Banks which it heads. This is composed by national Central Banks in charge of empowering the Union Central Bank policies at the country (k) level. National Central Banks hold reserves of commercial banks (R_{CBkt}) , accommodate their requests for cash advances (L_{CBkt}), and possibly buy bonds issued by the country government (B_{CBkt}) which have not been purchased by private banks.

At the beginning of the simulation, when no commercial banks are present (see section 2.3), Central Banks directly collect money of households and purchase the entire amount of bonds issued by governments.[9] However, in this transitory phase they cannot offer credit to firms.

National Central Banks' profits (π_{CBkt}) thus derive from interests on cash advances and bonds, from which we shall subtract interests paid on banks' reserves accounts.

$$\pi_{CBkt} = r_{bkt} B_{CBkt} + r_t L_{CBkt} - r_{re} R_{CBkt} \tag{39}$$

For simplicity reasons, we assume that Central Banks' profits are automatically redistributed to the local government.

The Union Central Bank is in charged of implementing the common monetary policy. For this sake it sets the discount interest rate following a Taylor rule based on the average level of inflation across member countries (Taylor, 1993; Smets and Wouters, 2007; Gerali et al., 2010):

[9] In this way they inject in the system the initial amount of legal currency that will then be invested by households in the creation of banks (and possibly firms), thus becoming banks' initial stock of consolidated reserves (i.e. reserves accumulated through time, net of short-term cash advances demanded to Central Banks). Indeed, as discussed in Caiani et al. (2016), in a closed system banks' consolidated reserves should coincide with Central Bank holdings of Public Debt. This is what happens also here if we consider the Currency Union as a whole, whereas at the country level banks can have positive consolidated reserves even when the local Central Bank does not hold any share of the national Public Debt, if they are able to attract reserves from other countries, for example through international trade.

$$r_t = \bar{r}(1-\xi) + \xi * r_{t-1} + (1-\xi) * \xi^{\Delta P}(\Delta P_{t-1} - \overline{\Delta P}) \tag{40}$$

where $\bar{r}$ is the exogenous long run interest rate, ξ is the parameter defining the speed of the adjustment, $\xi^{\Delta P}$ is the sensitivity to inflation, ΔP_{t-1} is the average level of inflation, and $\overline{\Delta P}$ is the inflation target.

2.1.5 Government

Government collects income taxes from households (h) and taxes on profits from firms (i) and banks (z).[10] Therefore, total taxes T_{kt} of country k are equal to:

$$T_{kt} = \sum_{h}^{H_k} \tau_k t y_{ht} + \sum_{i,\pi^*>0}^{I_k} \tau_k t \pi_{it-1} + \sum_{z,\pi>0}^{Z_k} \tau_k t \pi_{zt-1} \tag{41}$$

Government public expenditure G_{kt} takes the form of a lump-sum transfer which is equally distributed among households (TF_{kt}), thus providing additional purchasing power.

The public balance in a given period is the difference between revenues from taxes and government expenses, including also interests paid on public debt. When negative, we have a deficit DEF_{kt}. In the opposite case the government attains a budget surplus SU_{kt-1}. Possible budget surpluses are set aside to fund public expenditure in the next periods, thereby reducing the quantity of bonds to be issued (and the nominal value of public debt).

Country public deficit (DEF_{kt}) and debt (B_{kt}) are then given by:

$$DEF_{kt} = G_{kt} + r_{bkt-1} B_{kt-1} - T_{kt} \tag{42}$$

$$B_{kt} = B_{kt-1} - DEF_{kt} - SU_{kt-1} \tag{43}$$

The government employs two instruments to implement its fiscal policy: the level of public expenditure (G_{kt}) and the tax rate (τ_{kt}). These are adaptively revised from period to period based on the discrepancy between desired and past levels of public expenditure on the one hand, and expected and admissible levels of public deficit on the other hand. The desired level of public expenditure G^D_{kt} is simply defined as the initial real value of public expenditure G (set exogenously), corrected for the country average level of prices P_{kt} and productivity Φ_{kt}, to ensure that G^D_{kt} remains roughly stable compared to aggregate output: $G^D_{kt} = P_{kt}\Phi_{kt}G$. In addition, governments are committed to keep their deficit-to-GDP ratios ($d_{kt} = DEF_{kt}/Y_{kt}$) below a given threshold value indicated by d^{max}. Public expenditure and tax rates are then revised according to the following scheme:[11]

$$\textit{if } d_{kt-1} \geq d^{max} \textit{ and } G^D_{kt} \leq G_{kt-1} : \begin{cases} G_{kt} = G_{kt-1}(1 - U[0,\delta]) \\ \tau_{kt+1} = \tau_{kt}(1 + U[0,\delta]) \end{cases} \tag{44}$$

$$\textit{if } d_{kt-1} \geq d^{max} \textit{ and } G^D_{kt} > G_{kt-1} : \begin{cases} G_{kt} = G_{kt-1} \\ \tau_{kt+1} = \tau_{kt}(1 + U[0,\delta]) \end{cases} \tag{45}$$

$$\textit{if } d_{kt-1} < d^{max} \textit{ and } G^D_{kt} \leq G_{kt-1} : \begin{cases} G_{kt} = G_{kt-1}(1 - U[0,\delta]) \\ \tau_{kt+1} = \tau_{kt}(1 - U[0,\delta]) \end{cases} \tag{46}$$

$$\textit{if } d_{kt-1} < d^{max} \textit{ and } G^D_{kt} > G_{kt-1} : \begin{cases} G_{kt} = G_{kt-1}(1 + U[0,\delta]) \\ \tau_{kt+1} = \tau_{kt} \end{cases} \tag{47}$$

However, the tax rate is bound to vary within the range $\{\tau_{min}, \tau_{max}\}$, whereas G_{kt} is bound between a minimum and maximum share of GDP: $\{g_{min}Y_{kt}, g_{max}Y_{kt}\}$. In each period, the government repays bonds previously issued (which are assumed to have a 1-period duration) and pay interests to bond

[10] Remember that, as explained in section 2.1.2, taxes on profits generated at the end of period t are paid in period $t+1$.

[11] Admittedly, public expenditure and the tax rate on income and profits are kept constant in the very first periods of the simulation, till the first firm is created which takes just one period in the setup employed in the paper. Indeed, the fiscal scheme proposed in equations 44 to 47 can be employed only when at least one firm is preset, otherwise no employment, output, income, and profit would be generated.

holders. The interest rate on bonds is set as a function of the debt-to-GDP ratio (B_{kt}/Y_{kt}) and the Central Bank discount rate (r_{kt}):

$$r_{bkt} = \chi B_{kt}/Y_{kt} + r_t \tag{48}$$

Newly issued bonds (for a total value of B_{kt}) are split into 100 tranches ($b_{kt} = B_{kt}/100$) and put on the bond market where they can be purchased by commercial banks (both national and foreign), and possibly by the national Central Bank for the residual part. Finally, in the case of a default by a bank, the government steps in to guarantee depositors. For this sake, the government issues an additional batch of bonds, which is directly purchased by the Central Bank, and uses the liquidity collected to reimburse households and firms who lost their deposits in the default.

2.1.6 Firms and banks' endogenous entry and exit

As discussed in section 2.1.1 part of households' savings is invested in the creation of new firms and new banks. A threshold level of investment, equal to a share ϖ of the country average wage, is required to allow an individual household to participate in the creation of a new business, regardless its type. Furthermore, there is a maximum number of businesses in which a households can invest, equal to ψ.

In order to keep roughly stable the dimension of the banking sector relative to the productive one, we assume that a new bank enters when either the ratio between banks' and firms' number, or the ratio between banks' and firms' total net worth are below a given percentage η. Otherwise, a new firm is created. In the latter case, the new firm will be a tradable with probability c_T and a non tradable with probability $1 - c_T$.

The initial equity of the new entrant, may be a bank, a tradable firm, or a nontradable, is then determined as a random sample between the net worth of the smallest and larger agents in the sector[12]: when funds collectively invested by households are greater or equal to this level, the new organization is created and the first h randomly chosen investors required to collect the necessary funds become the shareholders. Otherwise, no firm (bank) enters the market and the funds originally allocated to equity investment are deposited at banks, being available to fund households' investment in the next period.[13] If instead funds dedicated to equity investment are not exhausted, the remaining part can be employed to create further organizations, their type and dimension being determined according to the same procedure explained above.

As for entrants' initial dimensions, also their initial productivities (ϕ), prices (p_{it}), and wages (w_{it}) are randomly extracted within a range going from the lowest to the highest values of incumbent firms in the sector, whereas sales expectations ($q^e_{i,t}$) are the maximum between the value extracted with this same procedure and $\frac{A_{it}}{w_{it}}\phi_{it}$. This latter represents the amount of goods producible given the value of equity, wage, and productivity randomly drawn. Firms whose net worth is below a threshold level, defined as the wage they would pay to workers $F_t = w_{it}$, default. Similarly, banks with a net-worth level lower than the national average wage default.

2.2 Simulation scheduling

Having analyzed in details the behaviors of each type of agent populating our artificial currency Union, we conclude by sketching out the sequence of events taking place within each round of the simulation.

1. Firms determine their desired production, their labor demand, the price of their output, the wage offered, and their desired R&D investment.

2. Firms interact with banks on the credit market and possibly receive loans. Banks possibly ask cash advances to the Central Bank to satisfy the mandatory liquidity ratio.

3. Firms interact with workers on the labor market.

4. Workers are paid and employed to produce firms' output and to perform R&D. Dividends generated in the previous period are distributed to equity holders, summing up to their current income.

[12] Given that this stochastic rule can operate only when some organization is already present, the first tradable and nontradable firms to enter the market have an exogenous initial net worth equal to A_0. In addition, in order to ensure that banks will be big enough to provide credit to firms, whose number is by far higher, the initial equity of banks has a lower bound defined as a multiple σ of the country's median firms' dimension.

[13] The same happens when households' individual investment does not exceed the threshold level.

5. Governments calculate revenues from taxes (on past period profits and current period households' income), determine the level of public expenditure and the tax rate for the next period, repay bonds plus interests to bond holders, and determine the quantity of bonds to be issued.

6. Bonds are put on the bond market where commercial banks buy it. The possible residual part is purchased by national Central Banks.

7. After having paid taxes and received the tax-exempt monetary transfer from the government, households compute their demand for consumption goods and interact with tradable and non-tradable firms on the correspondent good markets.

8. Firms compute their profits and update their net worth and shareholders' equity accordingly. Taxes and dividends to be paid in the next period to the government and to equity holders respectively are then computed.

9. Defaulted firms exit the market. Households equity investment takes place and new firms and banks are eventually created.

2.3 Simulations setup

Table 2 in the appendix provides a summary of the parameter values employed in the model. Each simulation period represents a quarter. Simulations have been run for 1000 periods. For each simulation setup we ran 25 Monte Carlo repetitions. In addition, for all simulation experiments we consider three different specifications regarding the number of countries belonging to the Monetary Union: an elementary 2-country model, and then a 6-country and a 10-country cases.

Besides setting the values of the behavioral parameters in the model, one of the most tricky aspects of the model calibration procedure concerns the setup of initial values of stocks and flows. Caiani et al. (2016) points out that this aspect has been quite neglected within the AB macro literature and very few models provide a detailed discussion of the logic followed to address this task. Initial stocks and flows must be compatible from an accounting point of view. That is, every financial stock should be a liability for someone and an asset for someone else, and every financial flow should represent an inflow for someone and an outflow for someone else. This implies that, as we move from individual to social or system-wide accounting, Copeland's quadruple entry principle (Copeland, 1949; Godley and Lavoie, 2007) must be respected. A distorted calibration, which does not satisfy these minimal requirements, can be a major source of logical and accounting inconsistencies that tend to buildup throughout the simulation, rather than fading away, thereby compromising the reliability of results. In addition, since most AB are strongly path-dependent, so that initial simulations conditions may exert a significant impact on the model dynamics, initial stocks and flows should be set at reasonable levels.

Caiani et al. (2016) then presented a sophisticated procedure to setup initial values of stocks and flows in an SFC manner, while reducing the modeler's arbitrariness in setting initial values. The present paper provides a simple and intuitive alternative to that procedure, inspired by the logic adopted in the "SIM" model presented in Godley and Lavoie (2007).

The fundamental feature of this procedure is that, instead of setting the initial values for each type of stocks and then distribute them across agents, we start from a situation where no stocks are present, and we let them to be progressively created and accumulated after the simulation starts. More precisely, not only real and financial stocks, but also firms and banks are absent in the initial period of the simulation.

Everything starts with public expenditure as the governments makes an initial transfer to resident households. Given that no private banks are present in this initial phase, it is the national Central Banks who buys government bonds, providing in this way legal currency to fund public expenditure. Since no firms, production, and goods are present, this lump-sum transfer is completely saved by households in the form of legal currency. However, part of this savings (see sections 2.1.1 and 2.1.6) are invested in the creation of new firms. Firms then start to employ workers and to produce consumption goods that they sell to households on the tradable or nontradable markets, according to their type. Firms also start to invest in R&D thus possibly increasing their level of productivity. As the number of firms increases also the banks will be created: households and firms will then acquire deposit accounts at the newly created banks in exchange for their legal currency, which will sum up to banks' reserves. Banks will start to give credit to firms, creating loans and matching deposits, thereby triggering the process of endogenous creation of money. At the same time banks will use their reserves to buy bonds

issued by the government. The system is now characterized by the presence of two interdependent monetary circuits, since both legal money, created by the public authority, and private credit money, created by banks, are present. As soon as households receive an income, and firms and banks realize positive profits, taxes will be paid to the government. With tax revenues and GDP increasing as new firms are progressively created, the debt-to-GDP ratio rapidly declines to reasonable levels. With tradable firms selling their output on the common integrated market, international flows of goods, deposits and reserves between countries will arise. Supranational credit-debt relationships, generating international flows of interests, will also arise because commercial banks can grant loans to foreign firms and buy bonds of foreign countries. Households will continue to invest in the creation of firms and banks till, after an initial phase where their number quickly increases, new entries and defaults will tend to balance each other. Technological progress, in the meanwhile, will differentiate firms and countries, impacting on their competitiveness. In turn, international trade and labor productivity dynamics will affect the evolution of employment, wages, prices, profits, aggregate demand, and GDP, which will eventually impact also on public finance, and on R&D investments itself. As the simulation goes on, the model progressively exits its transition phase and starts to display regular patterns and rather stable properties. The next section is dedicated to their analysis.

3 Simulation Results

3.1 Overview and consistency with international stylized facts

The dashboards in figures 6 to 8 present the dynamics of several important variables in a typical simulation executed under the two (left column), six (center), and ten (right) country scenarios, while table 1 provides some synthetic statistics on the 25 simulations runs performed under the three the baseline scenarios.

Variable	2 Countries	6 Countries	10 Countries	Euro Area (years)
Real GDP Growth	1.20 (0.041)	1.20 (0.039)	1.20 (0.039)	0.98 (04-15)
Labor Productivity Growth	1.19 (0.045)	1.19 (0.042)	1.19 (0.039)	0.90 (04-13)
Inflation	2.72 (0.067)	2.26 (0.101)	2.26 (0.078)	1.74 (04-15)
Unemployment	10.7 (0.795)	13.5 (1.208)	13.5 (0.918)	9.6 (98-15)
Public Debt/GDP	121.7 (12.121)	108.5 (23.514)	107.7 (22.645)	81.3 (06-15)
Private Loans/GDP	68.7 (5.732)	68.7 (7.857)	68.2 (6.798)	104.6 (06-15)
Public Deficit/GDP	1.2 (0.139)	1.0 (0.229)	1.0 (0.225)	3.2 (06-15)
Exports/GDP	19.5 (0.606)	32.0 (0.323)	34.5 (0.227)	40.0 (04-15)
Imports/GDP	19.5 (0.612)	32.0 (0.282)	34.5 (0.212)	38.1 (04-15)
Public Expenditure/GDP	44.1 (0.588)	46.2 (0.920)	46.3 (0.869)	48.6 (06-15)
R&D Investment/GDP	3.3 (0.082)	3.1 (0.012)	3.1 (0.099)	2.0 (06-15)
Household investment to GDP ratio	6.2 (0.176)	6.2 (0.136)	6.2 (0.173)	6.1 (06-15)

Table 1: Average simulated and empirical macro-variables in percentage values. Simulated averages and standard error from 25 Monte Carlo simulation runs. Empirical averages of Euro Area countries.

As we mentioned in the introduction, we tried to identify a baseline configuration of our artificial economy capable of yielding realistic and relatively stable dynamics. The adjective 'realistic' is employed to indicate a specification in which the values assumed throughout the simulation by key economic variables - such as real GDP and productivity growth rates, inflation rates, unemployment rates, debt-to-GDP ratios, exports and imports, etc. - are economically reasonable and broadly comparable to historical data for advanced countries, in particular for the Euro Area which constitutes

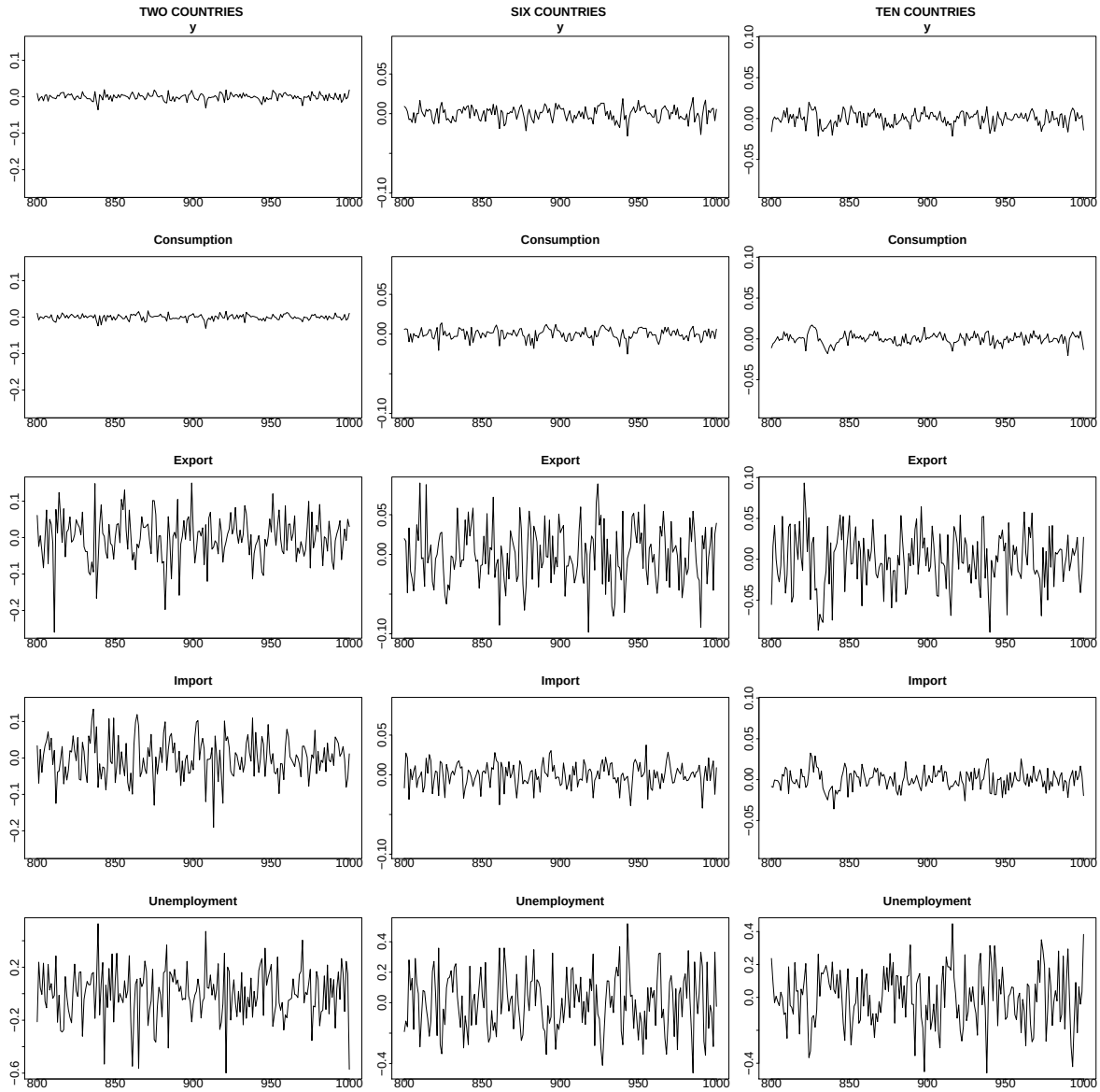

Figure 2: Cyclical components of simulated times series for Real Output (y), Consumption, Export, Import and Unemployment rate.

the natural point of reference for our work.[14] Table 1 highlights that our artificial Currency Union is broadly comparable to the EMU (last column) under many respects. Admittedly, the dimension of private debt over GDP is substantially lower than its empirical counterpart, whereas average public debt is relatively higher. The first discrepancy can be explained by the fact that no other form of credit than to firms is modeled. The greater debt-GDP ratio may be instead related to the initialization procedure adopted, which requires the government to trigger the development process through its initial public expenditure which cumulatively increases public debt since no taxes are collected until the first firms are created. However, the average debt-GDP ratio is not unreasonable compared to experience of many real countries - in particular in the two scenarios with more countries - and remains quite stable after the initial transition phase. Finally, the relative dimension of imports and exports compared to GDP in the two-country case looks lower than their empirical counterparts. This is likely to be caused by the smaller dimension of the international market for tradable goods under this scenario, where domestic firms account for a significant share of the common market. On the contrary, in the other two cases, the higher number of countries implies that domestic tradable firms account for a smaller share of the common market for tradable goods, so that demand for tradable goods by domestic consumers is more likely to be addressed to foreign firms.[15]

The panel in figure 6 displays that the model generates exponential growth of real GDP, coupled with an exponential increase in labor productivity. However, the process of development does not unfold in a smooth way, but rather through a a succession of economic cycles. Figures in panel 2 display the cyclical component of main economic aggregates, each one normalized by the trend component in order to allow a comparison on the same scale: in accordance with the empirical evidence the volatility of consumption is slightly below the volatility of real GDP, whereas exports, imports, and unemployment are significantly more volatile than real GDP.

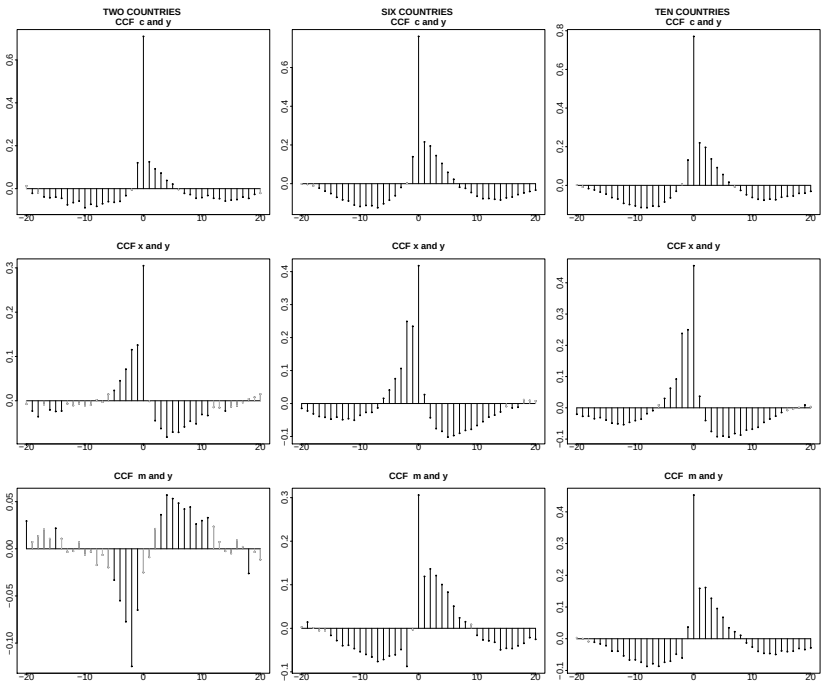

Figure 3: Simulated data average cross correlations of aggregate consumption (c), export (x) and import (m) with real GDP (y), computed from 25 Monte Carlo simulation runs.

Figures 3 and 4 show the artificial cross correlations of the cyclical components of consumption, exports, imports, public expenditure, public expenditure on GDP, and unemployment with the cyclical component of real GDP. The left, center, or right position of the peak in each correlation figure

[14] However, no attempt to calibrate the model so to minimize the distance with real time series available for the EMU was done.

[15] Similarly, production of tradable goods by domestic firms is more likely to be purchased by foreign customers since the domestic demand for tradable goods accounts for a smaller share of the total demand coming from the Currency Union as a whole. This increases the Exports/GDP ratio.

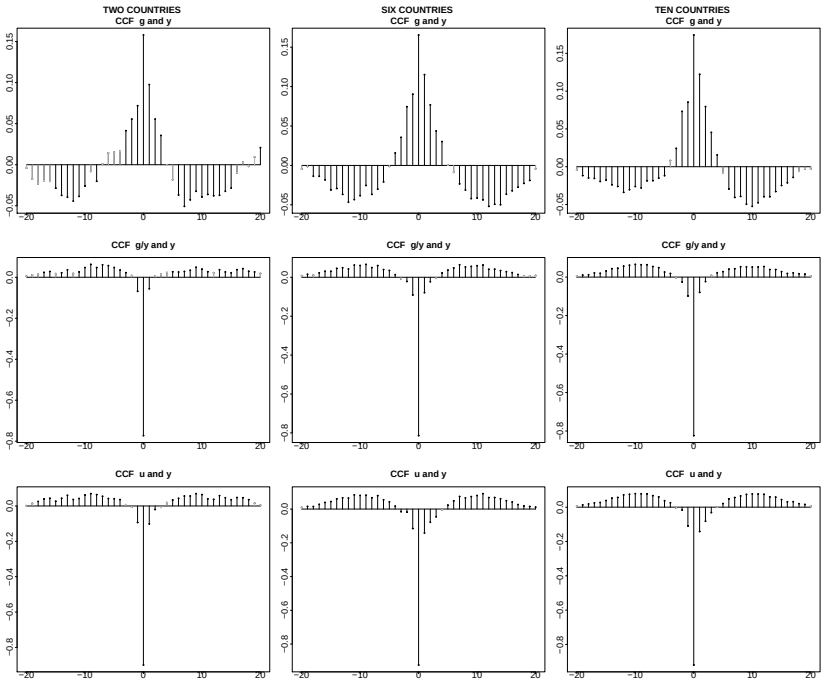

Figure 4: Simulated data average cross correlations of public expenditure (g), public expenditure over GDP (g/y) and unemployment (m) with real GDP (y), computed from 25 Monte Carlo simulation runs.

indicates whether the variable is lagged, coincident or leading with respect to output. The darker bars indicate correlations significantly different from 0. In accordance with the empirical stylized facts on the co-movements of aggregate indicators within and across countries (Uribe and Schmitt-Grohé, 2017), consumption, exports and imports are positively correlated with GDP, with the only exception of imports in the two-country case; real public expenditure is pro-cyclical in levels whereas public expenditure over GDP is strongly counter-cyclical; finally, unemployment is strongly countercyclical. The pro-cyclical character of consumption, exports, and public expenditure is not surprising, since the former two are direct components of real GDP, while public expenditure increases the available income of households, and thus aggregate demand and real GDP. Similarly, the positive correlation of imports is not surprisingly as increases in real GDP generally increase demand for both nontradables and tradables, and thus imports. However, in the two country case, the fact that domestic firms account for a significant share of the market for tradable goods may reduce the impact of increases in real GDP on imports. This possibly explains the non-significance of the correlation of imports with current output in this case. Finally, the positive correlation of G and the countercyclical character of G/GDP imply that government expenditure increases (decreases) less than proportionally with respect to GDP.

Figures in panel 6 and 7 also highlight that our results are consistent with other two important empirical regularities observed in international trade data: inflation in nontradable goods is higher than in tradables, whereas labor productivity growth in nontradables is lower than in tradables (De Gregorio et al., 1993; Bernard and Jensen, 1999; Bernard et al., 2003, 2007). In our model, prices in the tradable sector tend to be lower first of all as a consequence of the greater competitive pressure faced by tradable firms, which face a larger number of competitors on the international common market for tradables. For the same reason, international spillovers in the tradable sector tend to be greater than national spillovers in nontradable industries, providing a possible explanation for the enhanced productivity dynamics in the tradable sector. In turn, since higher productivity levels imply lower unit costs of production in the tradable sector, this concurs to keep prices of tradables lower.

Figure 5 provides the log-log plot of firm and bank size distribution with the log-normal (green line) and Pareto (red) fits of the upper tails: firms and banks significantly differ with respect to their size, and their size distributions is right skewed and display excess kurtosis and fat tails under all scenarios. Tests performed following the procedure explained in Clauset et al. (2009) show that both the power

law and log-normal hypothesis on the shape of the right tails are plausible, though the former is to prefer according to Vuong's likelihood ratio test, in line with the empirical evidence in the wake of Gibrat's contribution (Stanley et al., 1995).[16]

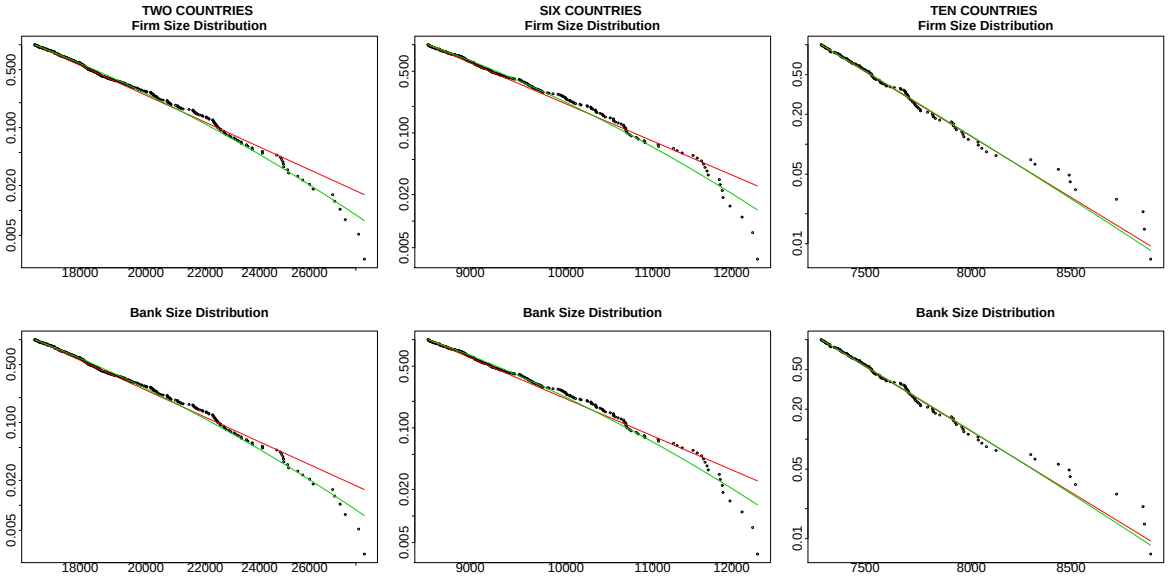

Figure 5: Firm and Bank size distributions. The figures also displays the log-normal (green) and power-law (red) fits of the right tails of the sample distributions.

Finally, figures in panel 6 also show that in all scenarios countries may significantly and persistently diverge in their real GDP and productivity levels over time, as observed in reality. In these simulations, some countries achieve a sufficiently high competitive advantage thanks to R&D and tend to keep it over the simulation while some others are affected by a persistent technological gap, though the size of these differences may widen or shrink over the simulation time span.

The dynamics of technological change in different countries is crucial to understand the evolution of the system. Figures 6 to 8 allow to get a first general idea about the interactions between technological change and several other processes undergoing in the real and financial sphere of the economy, and how they impact on firms' and countries' performance.

In the firms' perspective, an increase in productivity allows firms to produce more goods at a lower cost of production, thereby improving their competitiveness on the national (nontradable) or international (tradable) markets. More productive firms can sell their output at a lower price without eroding their profit margin. This also appears evident if we look at the two bottom lines of panel 7 where countries characterized by higher levels of productivity tend to have also lower price levels, whereas prices are higher in countries facing a technological gap. Therefore, more productive firms can attract more consumers and increase their sales and revenues. The consequent increase in sales expectations leads firms to expand production, possibly to an extent which increases their demand for labor, despite the labor-saving effect of technological change. As long as their increased output finds an outlet on the market, these firms will make higher profits, they will be relatively less financially constrained, and they will invest more on R&D. Higher R&D investments in turn enhance further their probability of achieving innovations, thereby widening the productivity advantage on competitors. This is the multiplicative engine which tends to foster firms' productivity differentiation.

However, this process is hindered by several counter-forces: first, the initial sales success may induce firms to increase the price of their output, possibly to an excessive extent which compromises their competitiveness; second, sectoral spillovers may allow firms suffering a productivity gap to rapidly catch up; finally, also the economic conjuncture in which innovations are carried out may play an important role in determining whether a temporary "forward flight" by an innovating firm is quickly reabsorbed or instead translates into a durable competitive advantage. In general, when demand is growing firms

[16] For a description of the procedure and a brief overview of the main findings of the empirical literature on firm size distribution see Caiani et al. (2016).

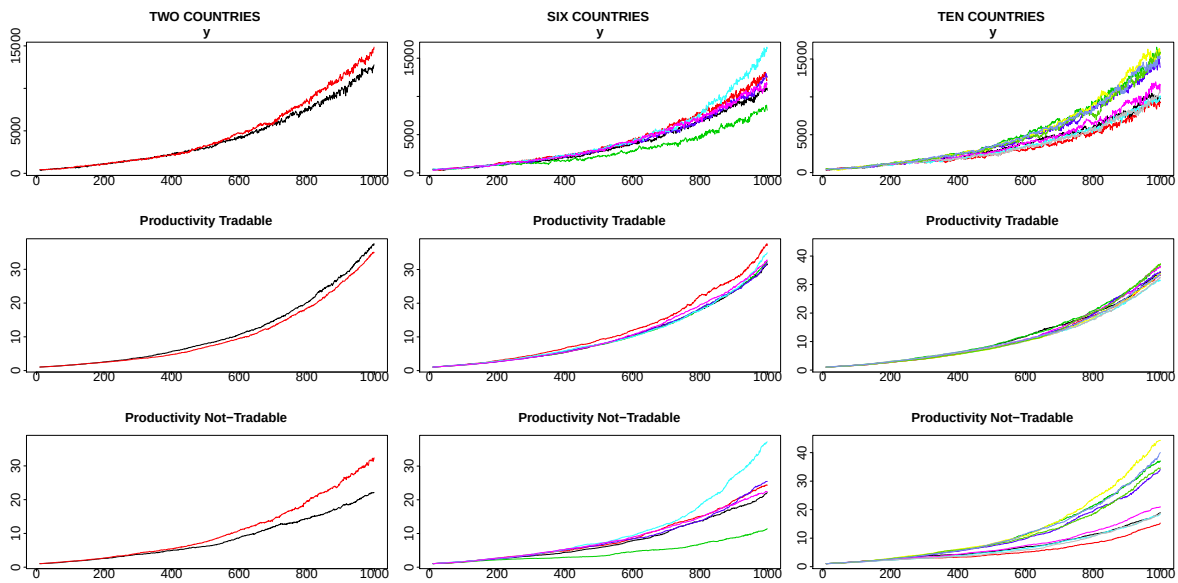

Figure 6: Country dynamics of real GDP (y), average productivity in the tradable and in the nontradable sectors.

suffering a productivity gap have greater chances to find an outlet for their production, so that they can continue to invest in R&D, possibly catching up with leading firms. On the contrary, economic downturns tend to exacerbate the Schumpeterian selection mechanism of firms, as less productive firms tend to suffer more from the fall in aggregate demand, their sales being the first to shrink. This increases their need for external finance to fund production and R&D investment, albeit the fall in revenues which negatively impacts on their net worth is likely to make banks less willing to satisfy their requests. Eventually, less productive firms will reduce or even stop to invest in R&D, thus becoming doomed to failure. However, during downturns also leading firms may go into troubles, for example if they have increase their output excessively and if they have borrowed too much just before the slump starts to hit.

In the countries' perspective, an increase in productivity obviously exerts direct labor-saving effects. However, unemployment may nonetheless remain stable, or even decrease if aggregate demand grows inducing firms to expand their production. On the domestic markets for nontradable goods innovations by firms tend to translate in increases of their market shares, at the expense of less productive competitors. More productive firms will then increase their production while less productive firms, seeing their sales shrinking and their inventories piling up in the warehouse, will reduce the level of activity. Much of the final net effect on labor demand of innovations achieved in the nontradable sector thus comes to depend on the magnitude of these opposite revisions, which in turn largely depends on the firms' relative sizes.

In the market for tradable goods, on the contrary, it is more likely that innovations exert a positive effect on employment of countries where they are achieved. Indeed, higher productivity levels translate into greater international competitiveness, possibly enhancing exports and GDP of the country. The raise of output thus tends to sterilize the labor-saving effect of technological change, preventing unemployment from rising and wages from declining. As a consequence, also demand for non tradable goods can possibly grow, leading to further improvements of employment and output dynamics.

This explains how the gain of a competitive advantage thanks to innovation may trigger an expansion phase. In addition, the improved GDP dynamics is likely to increase tax revenues and reduce public deficits so that the government may decide to cut tax rates and increase public spending, eventually boosting GDP growth. Also, because default rates are lower and profit margins more stable or even growing, households' investment in equity may increase: new firms can be created leading to further increases of employment and output, though their entrance may also exacerbate the competitive pressure on incumbent firms in the following periods, in particular on less productive ones. Finally, as long as productivity, wages, and prices are such to give the country a competitive advantage, the

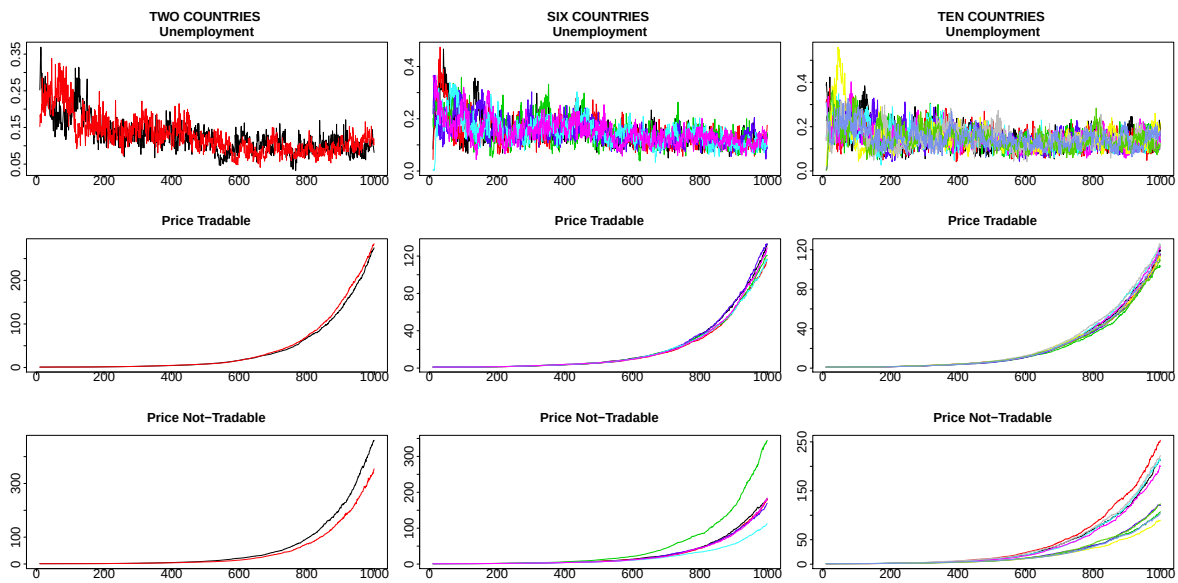

Figure 7: Country dynamics of unemployment, average price in the tradable and in the nontradable sectors.

ensuing current account surplus will cause a net-inflow of financial resources, improving the net lending position of the country.

However, these tendencies may be dampened and reverted by several counter forces. First of all, rising output levels and falling unemployment will generally boost inflation as firms, in response to an increase in their sales, will also rise prices in an attempt to increase profit margins. This will generally reduce the purchasing power of households, and thus real aggregate demand, while also tightening firms' and countries' competitive advantage.[17]

In addition, as unemployment goes down, workers' bargaining power increases pushing up wages. On the one hand, this increases aggregate demand and output levels. However, if wages continue to grow without being compensated by further increases in productivity levels, unit costs raise. This will narrow firms' profit margins and reduce internal funds, unless prices are increased accordingly to safeguard profits. However, this may eventually compromise tradable firms' competitiveness.

Furthermore, the rise of households' disposable income during the upward phase of the cycle will also increase imports of tradable goods from abroad, thus reducing the Current Account and, when this turns negative, the country's net foreign asset position. In addition, imports from abroad increase revenues of foreign firms which can use these additional funds to fund investment in R&D and catch up.

Since the long run dynamics of the model emerges from the chain of successive short run cycles, each one building on the previous one, the long-term system dynamics and the observed degree of convergence or divergence across countries can be seen as the path-dependent output of the same processes driving business cycles discussed above. These processes impact in a cumulative or even multiplicative way on the current value of economic variables. Depending on their persistence and magnitude, they can either give rise to temporary diversity which are later reabsorbed, or cause significant, long-lasting divergence between economic actors and countries.

Figures 6 and 7 show that in the long run, countries with higher productivity levels tend to be characterized by higher real GDP and lower inflation, whereas unemployment is quite similar. Plots also show that there is a tight relationship between productivity and GDP levels in the long run. On the contrary, though more productive countries tend to have, on average, also more solid public finance, countries with higher Debt/GDP ratios can indeed outperform countries with lower public debt levels. Similarly, having a long term productivity advantage does not necessarily imply that the

[17]The opposite adjustment process will generally take place in countries experiencing a drop in exports, though their flexibility in reducing prices may be narrow due to high unitary cost of production. This possibly explains why price differentials tend to remain positive also in the long run, as figure 7 displays.

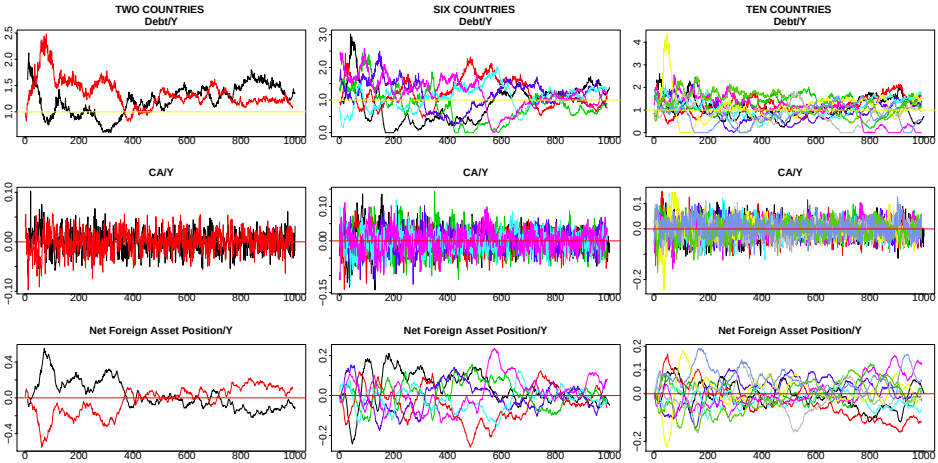

Figure 8: Country dynamics of debt over GDP (Debt/GDP), current account over GDP (CA/Y) and net foreign asset position over GDP.

country's Current Account is in surplus, nor that the country is a net lender (bottom line in panel 8). Indeed, even if more productive countries generally have higher exports, imports might be higher as well, possibly exceeding exports.

Finally, there is a clear inverse relationship between public debt and the net foreign asset position of the country (top and bottom lines of panel 8 respectively. See also the discussion on the relationship between fiscal and trade balances in section 3.2.)

3.2 Policy experiments on fiscal goals

In order to assess the impact of a change in the fiscal targets that government are committed to comply, we run six experiments assuming a change in the value of d^{max}, originally set at 0.03, occurring at period 500. More precisely, we test the following values of the parameter: $d^{max} = \{0.0, 0.1, 0.2, 0.25, 0.35, 0.4\}$. The first four scenarios, implying a fiscal policy contraction, correspond to the 'austerity' case, whereas the other two correspond to a fiscal expansion. In particular, the first scenario corresponds to the 'balance-budget' proposal of the Fiscal Compact and already transposed by several member countries into their legal order. It must be stressed that, since actual public deficits can be computed only after public spending and tax payments have taken place, actual deficits may be temporarily higher than d^{max}, so that this latter should be interpreted as a fiscal target rather than as an inviolable upper bound. In addition, given governments' behavioral rules specified in section 2.1.5, tax rates and public expenditure are progressively revised in an adaptive way. Therefore, we do not analyze the possible impact of sharp and sudden changes in fiscal policy.

The panel of figures 9 displays the impact of the fiscal regime switch on a selection of key macroeconomic aggregates in the two (left), six (center) and ten-country (right) cases. Values plotted are the Monte Carlo means of the across-country averages under the baseline (black line) and the other six policy scenarios. Dotted lines are the across-runs standard deviations of mean values. The plots in the first two lines show that all scenarios characterized by a permanent fiscal restrictions generate a significant drop of both real GDP and real productivity levels, associated with remarkable increases of unemployment rates. Expansionary policies instead tend to increase both real GDP and real productivity levels, though the improvement in the two-country case is almost negligible. Furthermore, permanent expansionary changes in fiscal targets always allow to reduce unemployment.

If we look at the dynamics of nominal variables there is a tight positive relationship between fiscal targets and the dynamics of prices: fiscal contractions are associated to very low level of inflation, which is almost zero in the two more restrictive cases. Vice-versa, a permanent increase of d^{max} generates higher levels of inflation.

Finally the dynamics of the debt-GDP ratios is particularly interesting, revealing a non-linear relationship with fiscal targets. While increases of d^{max} seem to be connected with greater public debt ratios in the two expansionary cases analyzed, the impact of policy restrictions is less trivial. Results highlight that in the two-country case fiscal contractions are able to effectively reduce the burden of public debt both in the medium and long run: average public debt-to-GDP ratios are indeed lower in all the austerity scenarios considered. However, strong fiscal contractions tend to be more effective in the short-medium run, but less effective in the long run compared to milder contractions, the levels of debt/GDP ending up to be lower in the $d^{max} = \{0.25, 0.2\}$ cases than in the $d^{max} = \{0.1, 0.0\}$ scenarios. That is, in the long run the depressive effect on GDP levels partially compensates for the reduction of public debt, so that the efficacy of strong and permanent reductions of fiscal targets in abating the debt burden is significantly dampened. This effect is exacerbated in the six and ten-country cases: the plots in these scenarios show that all austerity policies are effective only in the short-medium run, while being self-defeating in the long run. Debt-GDP ratios end up to be higher in these scenarios than in the baseline: in the most restrictive cases, debt-GDP ratios end up to be comparable to those obtained in the first expansionary case.

An initial raise in taxes (or a cut in spending), possibly occurring in more than one country as a consequence of the tighter fiscal targets, reduces the disposable income available for consumption, triggering a reduction in aggregate demand for domestic and foreign goods. The reduction of d^{max} however has also another important consequence: during recessions, when deficit-GDP ratios tend to raise as a consequence of the fall in GDP, tax rates increases and public spending cuts become more likely than in the baseline scenario, thereby exacerbating the ongoing recessionary dynamics. As a consequence, an initial increase of unemployment and default rates is now more likely to lead to an increase of taxes which tend to further depress demand, further dampening the dynamics of employment, wages, and prices. This in turn increases default rates. If the consequent fall in taxable income and profits is very pronounced, the fall in tax revenues is likely to increase deficit-GDP ratios even if tax rates are raising and public spending is constant or decreasing. Fiscal policy becomes very pro-cyclical as this induces further restrictions, which depress wages and unemployment more and more. However, a point will be reached when the reduction of prices will be such to increase workers real disposable income, allowing firms to unload their stock of inventories accumulated during the recession, thereby improving their sales expectations and making possible a recovery.

However, wage and prices adjustments have other two important effects: first, they reduce unit

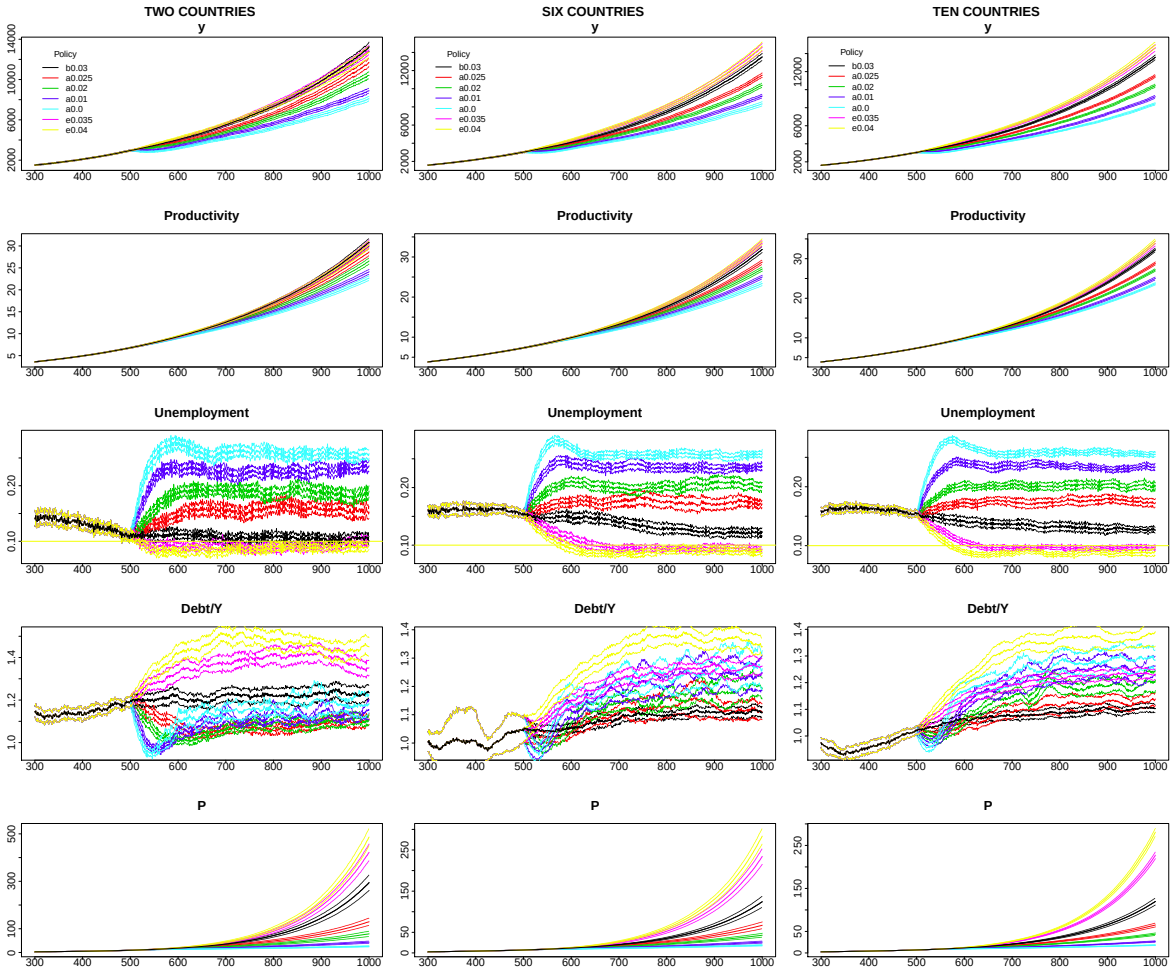

Figure 9: Effects of different fiscal targets on real GDP (y), average productivity, unemployment rate, debt over GDP (Debt/Y) and average prices (P). In black the simulation baseline specification with $d^{max} = 0.03$, in red $d^{max} = 0.025$, in green $d^{max} = 0.02$, in blue $d^{max} = 0.01$, in light blue $d^{max} = 0.0$, in fuchsia $d^{max} = 0.035$, in yellow $d^{max} = 0.04$. Average values from 25 Monte Carlo runs.

costs of production. For tradable firms this means having more room to maneuver when reducing price as a consequence of the fall in sales. Secondly, as disposable income declines, not only domestic demand, but also imports start falling. While these two adjustment processes can contribute to revert the recession of the country, they can be effective only in the measure in which they reduce country's demand for tradables and increase domestic firms' market share on the tradable market, at the expense of other countries. In other words these two latter effects concur to trigger a recovery in the measure in which they contribute to jeopardize other countries. Obviously the dimension of this effect is narrow when international trade is small compared to domestic markets, as it happens in the two-country case, or if only one country finds itself in the situation depicted above.

But when instead the size of the tradable market is greater and all countries follow a fiscal rule which tends to be more pro-cyclical during recession, this contagion channel becomes prominent, amplifying the recessionary effects of fiscal contractions through negative feed-backs between member countries, as observed in the six and ten-country scenarios of panel 9. All in all, the stricter fiscal goal does not only trigger a contraction of GDP, but also tends to increase the instability of the system amplifying fluctuations of real GDP, unemployment, an nominal variables both in the short and long run, as one can observe in figure 10. In these cases austerity tends to be self-defeating. On the contrary, fiscal expansions tend to reduce the volatility of main economic aggregates, so that the process of development proceeds along a smoother trajectory.

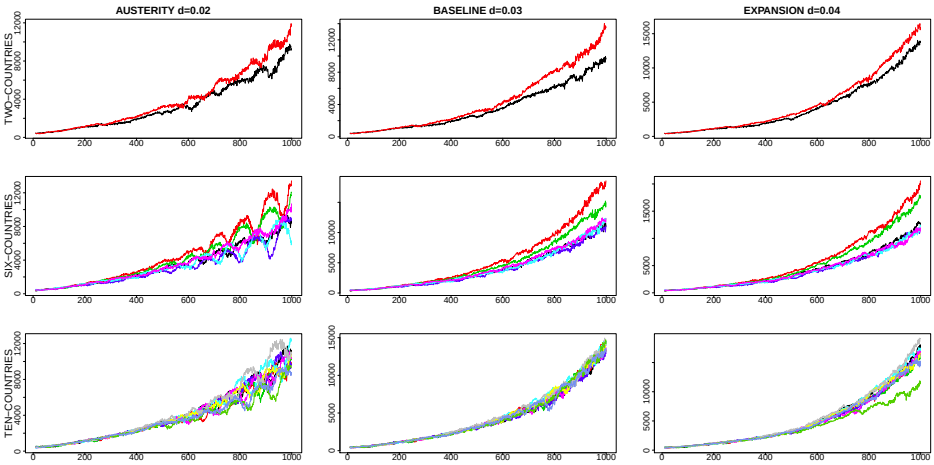

Figure 10: Country real GDP dynamics in different fiscal policy target scenarios: austerity $d^{max} = 0.02$, baseline $d^{max} = 0.03$, expansion $d^{max} = 0.04$.

However, we also notice that when the dimension of the Currency Union is greater the processes highlighted above do not impact on different countries in the same way. To perform such an analysis we divided countries in two groups: countries with a level of real GDP higher than the median level (in most cases associated with a higher level of productivity) and countries with a lower real GDP (and lower productivity) at the period when the permanent policy change occurs (i.e. period 500). For space and explanatory reasons we present the case of the fiscal contraction with $d^{max} = 0.02$ and the case of a fiscal expansion with $d^{max} = 0.04$. The effects discusses hereunder are reinforced under more extreme cases. Even though real GDP and productivity differentials do not seem to significantly diverge across scenarios, at least on average, the increase of debt-to-GDP levels observed in the austerity case is largely related to a remarkable increase of average debt-GDP ratio in poorer-less productive countries whereas it remains almost stable in richer ones. In less productive countries, the increase of the public debt burden is accompanied by a deterioration of their net foreign asset position, as shown in figures 12 and 13.

Indeed, rich and poor countries are also differentiated according to their productivity levels. Although wages may vary in a way that tends to reduce unit costs (w/ϕ) differences between tradable firms of high and low income countries, their dynamics is largely affected also by what happens in domestic markets. As a consequence, figures 11, 12, and 13 display that under all cases, unit costs of production tend to be higher in less productive countries than in more productive ones. Hence, tradable firms in poorer countries have lower profit margins and less room to manouvre when setting

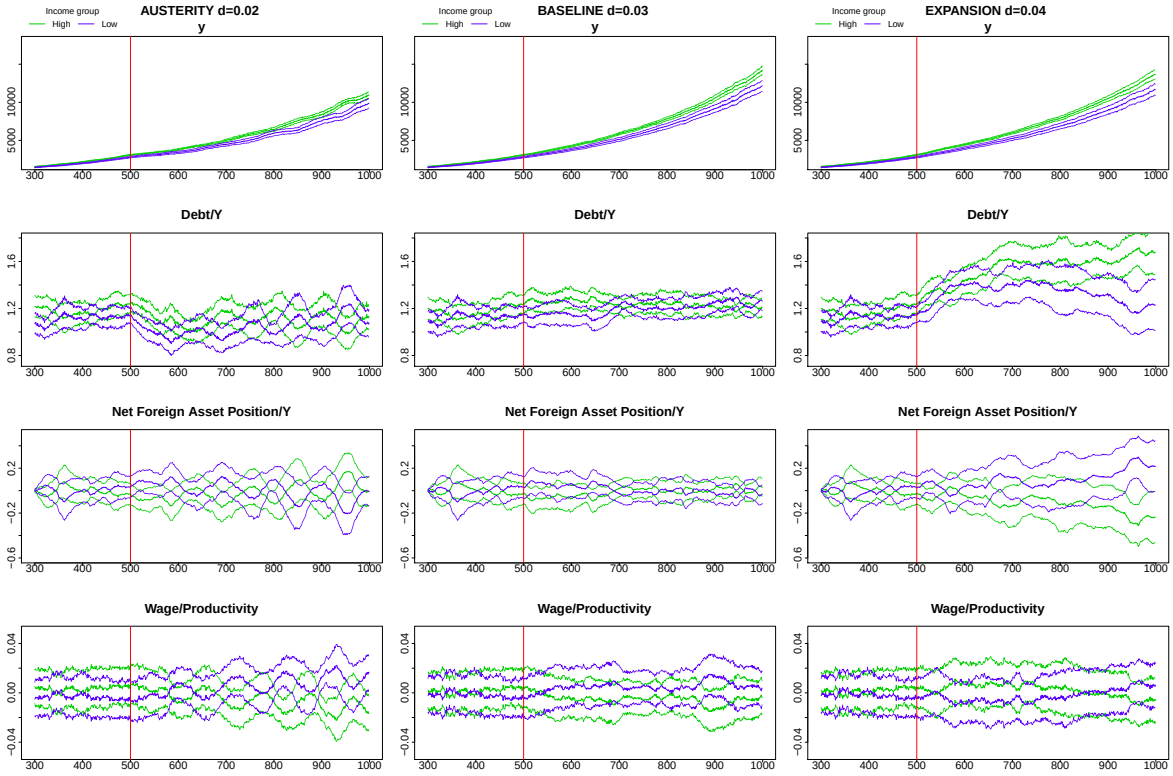

Figure 11: Two-country specification average macroeconomic country dynamics of high and low income countries. In green the averages of high income countries, in blue the averages of low income countries. Fiscal target changes at period 500, in austerity $d^{max} = 0.02$, in the baseline d^{max} is constant ($d^{max} = 0.03$), expansion $d^{max} = 0.04$. Dynamics of real GDP (y), debt over GDP (Debt/Y), net foreign asset position over GDP, average nominal wage over average productivity (Wage/Productivity). Average values from 25 Monte Carlo runs.

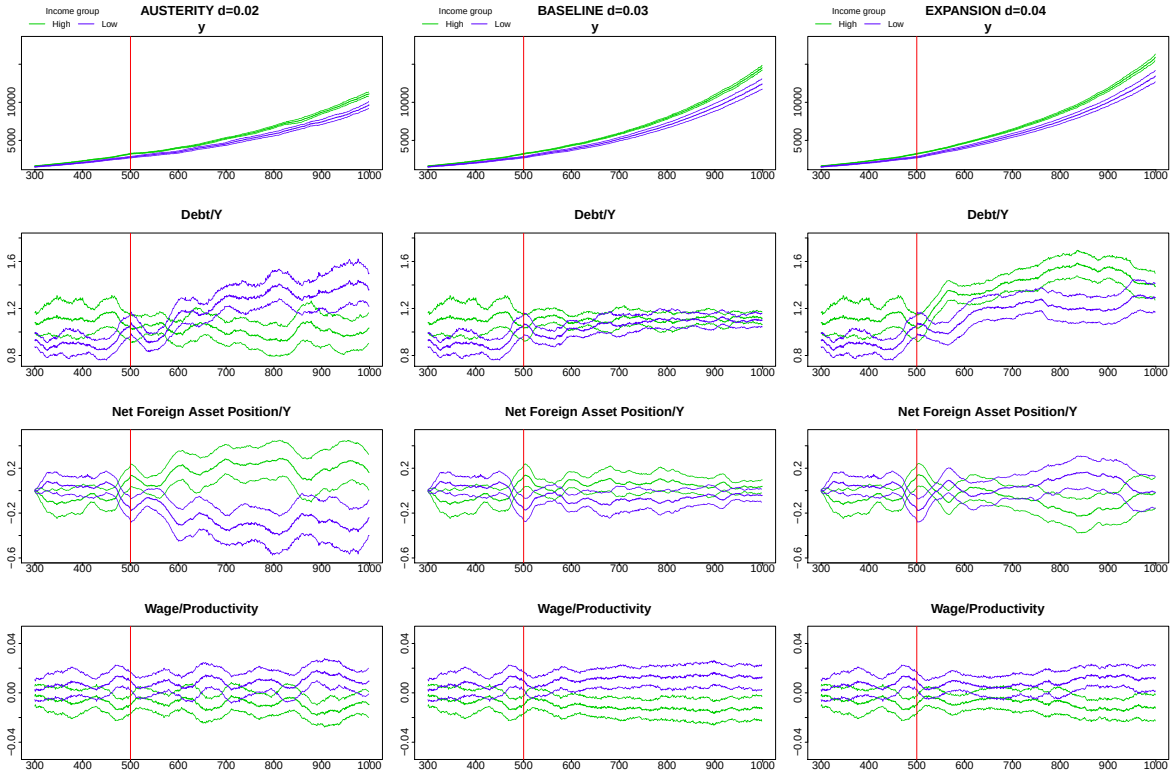

Figure 12: Six-country specification average macroeconomic country dynamics of high and low income countries. In green the averages of high income countries, in blue the averages of low income countries. Fiscal target changes at period 500, in austerity $d^{max} = 0.02$, in the baseline d^{max} is constant ($d^{max} = 0.03$), expansion $d^{max} = 0.04$. Dynamics of real GDP (y), debt over GDP (Debt/Y), net foreign asset position over GDP, average nominal wage over average productivity (Wage/Productivity). Average values from 25 Monte Carlo runs.

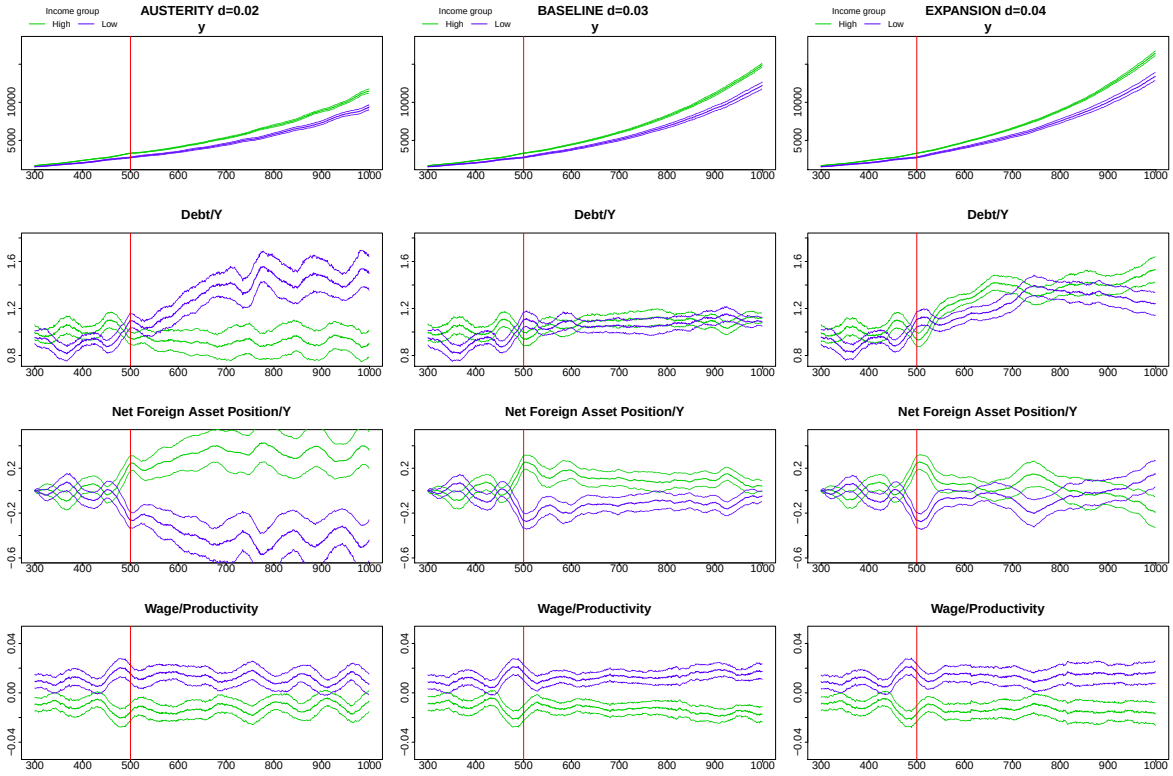

Figure 13: Ten-country specification average macroeconomic country dynamics of high and low income countries. In green the averages of high income countries, in blue the averages of low income countries. Fiscal target changes at period 500, in austerity $d^{max} = 0.02$, in the baseline d^{max} is constant ($d^{max} = 0.03$), expansion $d^{max} = 0.04$. Dynamics of real GDP (y), debt over GDP (Debt/Y), net foreign asset position over GDP, average nominal wage over average productivity (Wage/Productivity) Average values from 25 Monte Carlo runs.

prices compared to their competitors in rich countries, in particular during recessions where firms tend to lower prices to recover sales: default rates thus turn out to be higher in less productive countries: here tradable firms either see their profit margin rapidly evaporating when they are forced to reduce prices, or their sales shrinking if prices are already at the unit cost lower bound. In the latter case firms have to wait for wages to fall before being able to gain competitiveness, thereby being more exposed to defaults.

In the recessionary and volatile context triggered by the austerity turn in fiscal policy, less productive tradable firms will thus be more fragile and less flexible in adjusting prices. This implies that poorer-less productive country have more difficulties, and need more time, to adapt during recessions, experiencing on average deeper and more frequent current account deficits than in the baseline. These deficits then translate into a reduction of tax revenues, culminating in higher public deficits and explaining the raise of debt-GDP levels associated with the worsening of the net foreign asset position in poor countries relative to richer ones.

4 Conclusions

The paper presents an Agent-Based Stock Flow Consistent Multi-Country model of a Currency Union. Besides the possibility of running simulations with a variable number of countries, which is per se a major novelty in the AB macroeconomic literature, the model shows several other important features. In particular, we adopted an SFC framework (Godley and Lavoie, 2007) along the line traced by Caiani et al. (2016, 2017) to ensure the accounting consistency of the model and to provide a fully integrated representation of the real and financial sides of the economic system depicted. In this respect, we also present an innovative procedure to initialize the simulation in an SFC manner, where initial injections of money through public expenditure allow households to create firms and banks, thus triggering the process of economic development. In addition, we introduced endogenous technological change in an evolutionary flavor, following the long lasting tradition on the wake of the seminal contribution of Nelson and Winter (1977, 1982). Innovation dynamic plays a crucial role in the model, allowing firms and countries to differentiate from each other, and concurring with aggregate demand and international trade to steer the dynamics of the model in both the short and long run. Finally, another add-on to the current AB macroeconomic literature is the endogenization of the entry-exit process of firms where the creation of new firms comes to depend on households' investment in equity, defined as a function the expected rate of return and the perceived riskiness of equity investments, compared to interests paid by banks on deposits.

The model was then employed to assess the effect of a change in the fiscal regime of member countries, which takes the form of a permanent variation of the maximum deficit-to-GDP ratio allowed. Each simulation experiment has been performed under three scenarios, differentiated for number of countries belonging to the Union. In this way we aimed to assess whether, and how, the dimension of the Union (i.e. countries' numerosity), and more precisely the dimension of the common market for tradables, affect the efficacy of policies tested.

Before performing our policy experiments we made an attempt to validate the model showing that the configuration employed for our artificial Currency Union yields economically reasonable values for the dynamics of key economic variables, broadly comparable with historical data and available stylized facts for advanced countries.

Policy experiments show that fiscal expansions tend to improve the dynamics of real GDP, labor productivity, and employment, though being generally associated to higher levels of public debt and higher, though not excessive, levels of inflation. On the contrary, permanent fiscal contractions have strong recessive effects which attenuate their efficacy in reducing public debt-GDP ratios in the long run. When the Currency Union encompasses a higher number of countries, and international trade between member countries is more prominent, permanent fiscal contractions are not only recessive but also self-defeating in the medium and long run: indeed, average values of public debt ends up being higher than in the baseline. This increase is largely caused by an increase of debt in poorer and less productive countries mirrored by a corresponding deterioration of their net foreign asset position, suggesting that permanent fiscal contraction exert an asymmetric impact on more and less productive countries. In addition, we found that fiscal contractions tend to exacerbate the volatility of main economic aggregates both in the short and long run, whereas fiscal expansions tend to dampen it. Our assessment of the effects of different fiscal policies in the context of a Currency Union characterized by strong trade linkages is thus generally consistent with the conclusions of De Grauwe and Ji (2013), Hein et al. (2011) Semieniuk et al. (1 14), and Perez-Caldentey and Vernengo (2012), and with results obtained by Dosi et al. (2013, 2015), and Teglio et al. (2015) using similar modeling approaches: with respect to these works our main aspects of novelty are represented by the asymmetric impact of fiscal restrictions on high and low-productivity countries, and by the scale-dependent efficacy of fiscal austerity in the long run, which is greatly affected the relative size of the common market for tradables, compared to domestic markets for nontradables.

Our analysis is susceptible of being enlarged, deepened, and improved under many respects. First, while the present work focused on the impact of permanent policy changes in the fiscal targets of all member countries, one may wonder what would be the effect of fiscal consolidations implemented through temporary fiscal interventions, or through state-contingent policies, or yet through asymmetric policies. In addition, the interaction between monetary and fiscal policies should be addressed as well.

On the modeling side, the framework here proposed can be largely improved, in particular on the financial side which at this stage presents very simplified matching procedures on the international credit and bond markets, and totally neglects the role of foreign direct investments. As a consequence,

most of the dynamics of international financial flows across countries is determined by international trade (i.e. by the trade balance) while in reality also independent financial transactions across borders can be of topical importance to analyze the the possible emergence of real and financial imbalances between countries. Similarly, given the relevance of international trade and unit costs asymmetries in our model, also the possible interaction between fiscal policies and labor market regulation could be further explored.

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A Baseline Setup

Table 2: Parameters

K: Number of countries	2, 6, 10	μ_2: Minimal reserve requirement parameter	0.1
H: Number of Households	500	ι_l: Loan probability parameter	1.0
l^S: Workers' labor supply	1.0	χ: Loan interest parameter	0.003
ψ: Matching parameter	10	ι_b: Bond probability parameter	0.1
υ: Wage revision probability parameter	1.0	r_{re}: Interest paid on banks' reserves	0.0
w_0: Initial wage	1.0	r_{b0}: Initial interest on bonds	0.001
ϕ_0: Initial productivity	1.0	$\bar{r}$: Taylor rule long run interest rate	0.0075
τ_0: Initial tax rate	0.4	ξ: Taylor rule adjustment speed parameter	0.8
c_y: Propensity to consume out of income	0.9	$\xi^{\Delta P}$: Taylor rule sensitivity to inflation	2
c_D: Propensity to consume out of wealth	0.2	$\overline{\Delta P}$: Inflation Target	0.005
δ: Adaptive Parameter	0.03	d^{max}: Maximum deficit-GDP ratio	0.03
c_T: Share of tradable	0.4	tau_{min}: Minimum tax rate	0.35
β: Hotelling circle parameter	2.0	tau_{max}: Maximum tax rate	0.45
λ: Liquidity preference parameter	0.2	g_{min}: Minimum G/GDP	0.4
θ: Share of sales as inventories	0.2	g_{max}: Maximum G/GDP	0.6
γ: R&D expenditure parameter	0.03	η: Banks-firms minimum proportion	0.03
ν: R&D success probability parameter	1.5	ϖ: Minimum investment threshold parameter	0.1
ρ: Share of profits distributed	0.95	A^0: First firms' initial net worth	10.0
ζ: Deposit interest-discount rate ratio	0.1	σ: Banks' minimum dimension relative to firms	4
μ_1: Total credit supply parameter	20		